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MOTIVATING CRITICAL THINKERS IN FOURTH GRADE SCIENCE: ACTION RESEARCH PROMOTING 21ST CENTURY SKILLS THROUGH TECHNOLOGY INTEGRATED PROJECT-BASED LEARNING.

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DEDICATION

To EJ, my husband and partner in life, thank you for supporting me in all that I do, especially through every step of this process. Your encouraging words and reminders of who I am, when I faltered, have given me the strength I needed to make this dream come true. I am blessed to have you walk with me through all the moments of our life together.

To my children, thank you for being my biggest cheerleaders. Marissa, my beautiful daughter, your drive, determination, and self-confidence amaze me. You tackle every opportunity with purpose and never back down. James, my loving son, you amaze me with your perseverance and motivation. No matter what comes your way you never give up. The two of you are my greatest accomplishment. You inspire me and your endless support means more to me than you will ever know.
ABSTRACT

The purpose of this action research was to evaluate the integration of technology with project-based learning to determine its effect on critical thinking, science content knowledge, and motivation for science learning for fourth grade students. There is increased motivation for student-centered learning environments that engage students in critical thinking, motivating students to learn in active ways that relate to the real-world applications. Project-based learning is based in constructivist learning theory, where students construct knowledge through active learning strategies. This research explored three questions related to increasing science content knowledge, critical thinking skills and motivation to learn science content through the implementation of technology integrated project-based learning. The first question looks at how technology integrated project-based learning affects the critical thinking skills of fourth grade students ($n = 25$). The second question looks at how fourth grade students’ life science content knowledge changes while integrating technology in a project-based learning unit. Finally, the last question addresses how integrating technology in project-based learning effect motivation to learn science content in fourth grade students.

Quantitative data analysis showed significant growth in student’s science content knowledge. Survey results were not significantly higher for intrinsic or extrinsic motivation. Technology integrated project-based learning had a positive impact on critical thinking skills. Students used critical thinking skills to evaluate information, plan for next steps in the process of learning, determine if information was missing from their
body of knowledge, and search for missing information to prepare a complete picture of their animal’s life. Having an authentic audience gave students a purpose for their learning. Collaboration offered students a purpose for their learning, helping to focus them on the important information needed to complete their tasks. This research has implications for technology integration within the project-based learning classroom and for growing 21st century skills. Project learning environment increased interaction between science content and critical thinking skills deepening student understandings. Giving students a choice and voice in the learning process motivated them because they were personally invested. Technology allows students to collaborate in new and different ways, including sharing knowledge and co-creating artifacts.
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CHAPTER 1
INTRODUCTION

National Context

The teaching of critical thinking skills has been discussed in our nation since the release of *A Nation at Risk*, which was generated by the National Commission on Excellence in Education (Wang & Zheng, 2016). There is no set of standards in place to test students on critical thinking. Clarity, accuracy, precision, relevance, depth, breadth, logicalness, significance, and fairness are words used to identify the intellectual standards presented by Paul and Elder (2013) lead to the act of thinking critically about information. One study indicates seven definitions of critical thinking, including the most prominent of the definitions which focuses on “critical thinking as judgement” (Moore, 2013, p. 506). Critical thinking is analyzing information by asking questions, reflecting, and making sense of the information based on the context (Elder & Paul, 2013; LaPoint-O’Brien, 2013; Paul & Elder, 2012; Vitulli & Santoli, 2013).

Critical thinking is a skill that will be used long after students’ complete formal schooling. Employers today search for candidates that can think critically about issues and problems and form new ideas for solving those issues and problems (Buck Institute for Education, 2013). Hart Research Associates (2013) surveyed employers to learn what skills they most want to see in job candidates. Of those surveyed, 93% of employers surveyed considered critical thinking, communication and problem-solving skills higher than the applicant’s college major. “Critical thinking has increasingly come to be seen as
the crucial underlying skill or attitude to be developed” (Chirgwin & Huijser, 2015, p. 337). As teachers, we must cultivate critical thinkers who ask questions, gather information, make decisions, think about alternatives, and communicate effectively (Paul & Elder, 2012). Critical thinking skills need to be developed in students because these skills are the basis for future learning and thinking.

Learning the intricacies of science requires students to be open to the world around them. Students observe, question, create hypothesis, evaluate results, and communicate results of experiments when studying science. All of these tasks require students to think critically while working through real world situations (Krajcik & Blumenfeld, 2006). “Many learners have not grasped the meaning of thinking as an objective of learning and education, and thus questions, which require thinking, are challenging” (Birgili, 2015, p. 72). Thinking is a skill that needs, to be taught, practiced, and cultivated. The ability to think critically involves considering information, analyzing the information, and making conclusions about the information (Baser, Ozden, & Karaarslan, 2017; Elder & Paul, 2008, 2013).

Motivation is an area that has a direct impact on education. Designing effective instruction can impact student motivation. Focusing on teaching methods that contribute to an increase in student motivation can have a direct effect on the motivation levels of students (Siew & Mapeala, 2017). Students who return to a task during free time of their own accord can be considered to have motivation for that topic or activity (Fortus & Vedder-Weiss, 2014). Student motivation can have an effect on their level of learning. Traditional teaching practices do not motivate all students; we need to reach them where they are by tapping into their interests (Ball, 2016; Brown, Lawless, & Boyer, 2013).
Local Context

This action research took place in a fourth-grade classroom at Firebird Academy in a suburban area outside a large metropolitan city in the Southeast region of the United States. Firebird Academy is a kindergarten through seventh grade suburban public school. The school population consists of 54% male students and 46% female students with 31% of students receiving free or reduced lunch. According to the state Department of Education, Firebird Academy has an “A” school grade (State Department of Education, 2018). An overall 67% of the students enrolled in Firebird Academy scored at or above satisfactory rating on end of year English Language Arts (ELA) state assessments, while 72% of students scored at or above satisfactory rating on the end of year math state assessments (State Department of Education, 2018). Fourth grade students at Firebird Academy had the highest percentage of satisfactory or above rating, with 74% in ELA and 84% in math. Caucasian students make up the largest part of the population at 78% followed by Hispanic students 11%, African American students 4%, Asian 3% and the remainder are a combination of two or more races 4%.

With the increased emphasis on testing in the school district, the focus has been increasingly moved to high stakes test results. I have worked with teachers who do not foster thinking critically to solve problems but follow the highly scripted programs adopted by the school district. The need to cover an increased number of standards could be blamed for the reduced amount of time for critical thinking skills to be taught. The pressure on teachers to perform and raise test scores is intense and the district wants to associate test scores with pay levels further applying stress on teachers.
Time constraints cause science learning to be a lower priority than reading, writing, and math. Students in fourth grade complete statewide testing on reading, writing, and math making the emphasis on these subject areas a higher priority. Science and social studies are given a limited amount of time each day and they are often the first to get cut out if more time needs to be spent on another subject. Science at my school consists of teaching from the district adopted science program in the 25 minutes per day that is allotted. That limited time period is further reduced by splitting it between science and social studies. Most teachers teach directly from the teacher’s guide while students follow along in their student workbook answering the textbook questions as they work through the pages. This approach does not give students access to real world experiences in the realm of science (Bell, 2010). Although there are hands on activities in the science program, there is little time for set up and completion of these activities and they do not come with the supplies teachers need to complete them. This time slot is at the end of the day, if there is time remaining, when students are winding down from a full day of learning. Critical thinking in science in this environment does not have time to develop given the limited time frame (Ladewski, Krajcik, & Harvey, 1994).

**Statement of the Problem**

Intermediate grade students lack critical thinking skills necessary to solve problems in the classroom and beyond. Students want to be given the answer to questions and regurgitate the answers. Halpern (2003) states that the ability to think critically has always been important but even more so for the 21st century learner because the world has become increasingly technical and complex. Critical thinking is important to the process of learning (Paul & Elder, 2008a). Students need to be challenged to think
critically while learning about the world around them. “When the focus of classroom activities is directed toward student-led approaches and away from teacher-led approaches, learning tends to be more meaningful since students are the ones who generate what is needed to advance their skills” (Yancy, 2012, p. 2). We need to create valuable learning experiences for students to stimulate critical thinking skills (Paul & Elder, 2008a). Project-based learning exposes students to meaningful material and allows them to think critically to solve problems or present information they are invested in (Grant, 2011; Krajcik & Blumenfeld, 2006).

Purpose Statement

The purpose of this action research was to evaluate the implementation of technology integrated project-based learning to increase critical thinking skills in science for fourth grade students at Firebird Academy.

Research Questions

This research will be explored with the following questions:

1. How does the implementation of technology integrated project-based learning affect the critical thinking skills of fourth grade students?

2. How does the implementation of technology integrated project-based learning affect the science content knowledge of fourth grade students?

3. How does the implementation of technology integrated project-based learning affect the motivation to learn science content in fourth grade students?

Researcher Subjectivities and Positionality

As a public-school educator, I have worked to provide valuable learning experiences for my students that will help develop a curiosity and lead to a life-long love
of learning. I am continuously interested in learning new things, whether it is something interesting on a personal level or a topic that leads to a better learning experience or environment for my students. The past few years have been full of transition, I moved several times first to a new state and then again within the state. Being exposed to many different environments has given me a new perspective on what education looks like depending on the location. Each district, each administration, and each group of people I have worked with had a different perspective on what education should look like. One thing was the same at all locations, they all had an emphasis on state testing results. When everything is focused on testing and “this is how we do it here,” it leaves little opportunity for teachers to be innovative. Technology integration has been a valuable part of my teaching beginning early in my career. As I have grown as a teacher, my love of technology has grown into teaching my students and other teachers how to use technology to enhance the current curriculum.

As a child, I was exposed to computers in my home because my father worked with them in his career. This exposure led me to want to learn about new technologies throughout my life and into my teaching career. As a first-year teacher, I worked with a mentor teacher who had a love of technology and worked to get the new technology at our school put in our classrooms. I previously worked in a school with a one to one technology roll out for all students, where each student was given an iPad to use for school. Having a device for each student changed the way I teach, I worked toward a paperless classroom where students electronically created, completed and submitted assignments. The school I work at now has technology resources available for check out, which can make it difficult if the computer carts are being used by someone else. My
administration and colleagues have been supportive, and I now have a cart checked out to me on a regular basis. Students are exposed to technology in all aspects of their lives; they have grown up in a world where they have only known instant access to the knowledge they seek. This access to instant answers can lead students to expect everything they do to come instantaneously. It is important to realize the importance of teaching students to use the technology in appropriate ways and help them to think through how and why they use these tools.

Integrating technology is important because students today have not known a world without technology. It is my responsibility to create digital citizens who know appropriate uses for technology and are prepared for a future that is led by technology. This preparation begins with me in the classroom with real world applications or projects where students are actively learning. “Student’s engagement in high-level thinking is a notable strength of active learning” (Stolk & Harari, 2014, p. 231). Teaching and learning are a constant process that is ever evolving and changing based on what is changing in the world. To help mold students to use technology in a way that advances their thinking and learning, I need to learn about new forms of technology, applications, programs, and devices that can bring innovation and interest to my students and my classroom (De Silva, Chigona, & Adendorff, 2016; Grant, 2016).

As a pragmatist, I see the world as constantly being renegotiated and changed. The reality of the classroom has changed, and I must change with it. Students do not learn in the same ways they did even a few years ago. I must change how I look at teaching, learning, and my view of what a classroom looks like. Pragmatism considers what is to be studied, and how it is to be studied (Creswell, 2014). As education has changed, the
way we look at problems in education has changed as well. At the beginning of my career, the technological resources available to me were limited, and my students were exposed to computers once a week or every other week. The evolution of technology in the last thirteen years has given me the opportunity to increase my skills and the skills of my students. I find myself learning new and useful techniques daily and transferring that knowledge to my students. As I look at the scope of my research topic, I am aware of the current level of motivation among students and their limited desire to expand their knowledge. I am also aware of my biases that students are the true owners of their knowledge, and they are responsible for their learning. Since I was the researcher and the teacher, my positionality was that of an insider (Herr & Anderson, 2005). I examined the effects of project-based learning on critical thinking skills, science content knowledge levels, and motivation to learn science content. I was aware of the influence I have on students and their work within the project-based learning assignments and technology they choose to use (Dwyer & Buckle, 2009). I was aware of the student perceptions and expectations for facilitating and grading projects completed by the students. I also needed to be aware of the perceptions of colleagues and expectations of the administration at my school. I was careful when reporting findings to colleagues and administration because of my insider positionality.
Definition of Terms

21st century skills: 21st century skills include essential skills for success in the current world. Creativity, collaboration, communication, and critical thinking are among the important skills students need for success (The Partnership For 21st Century Skills, 2009). Students need to be able to solve problems by looking at all aspects of a situation to determine the best way to proceed (Jonassen, 1997, 2000). Technology plays an important role in the development of 21st century skills, students need to have skills to effectively and appropriately use technology within the learning environment (The Partnership For 21st Century Skills, 2009).

Collaboration: Collaboration includes listening and communicating for a range of purposes (The Partnership For 21st Century Skills, 2009). Ertmer and Simons posit “Collaboration is a key component of PBL learning environments, as it allows students to draw on each other’s perspectives and talents in order to more effectively devise solutions for the problem(s) at hand” (Ertmer & Simons, 2006, p. 43). Collaboration on projects can lead to a deeper understanding because students have the opportunity to discuss and reflect on information they encounter (Krajcik, Blumenfeld, Marx, & Soloway, 1994). For the purpose of this student, collaboration is defined as students working together to integrate knowledge, create artifacts, and share knowledge.

Constructivism: Constructivism is an active learning process where learners’ construct knowledge through interaction with the environment and interpretation of meaning (Cetin-Dindar, 2016; Hannafin, Hannafin, Land, & Oliver, 1997; Jonassen, 2006). In a constructivist learning environment, the teacher acts as a
facilitator, guiding students in their learning (Cetin-Dindar, 2016; Vidmar, 2011). The constructivist classroom gives students opportunities to actively construct their knowledge through collaboration, creation, problem solving, critical thinking, and sharing.

**Critical thinking:** Critical thinking has many different definitions in the academic world. Moore (2013) points out judgement as one of the most prominent focuses in the definitions of critical thinking. To be a critical thinker one must evaluate information and make judgements about what has been presented based on what is known about the subject and the world (Paul & Elder, 2012). “However, the structure and process of critical thinking may be defined and elaborated, the very awareness that critical thinking is crucial represents a significant advancement in self-knowledge” (White, 2010, p. 14).

**Digital collaboration:** Digital collaboration involves the use of technology when collaborating. Students engage in collaborative tasks through the use of digital tools like shared documents, comments in a digital document, annotation, virtual meetings, and a variety of other tools (Scalise, 2016; The Partnership For 21st Century Skills, 2009). In this study digital collaboration is defined as students using digital tools to complete work in an online environment.

**Motivation:** Motivation can drive students to want to do more and lead them to a higher level of success (Shin, 2018). “Motivation, however, can also be conceptualized as a qualitative variable that represents different value or goal orientations, different ways of processing or attending to information, and different cognitions about one's performance” (Ames & Ames, 1984, p. 535). Motivation can be
intrinsic or extrinsic, students may be internally motivated or externally motivated (Ryan & Deci, 2000). Intrinsic motivation Extrinsic motivation

**Problem solving:** Problem solving involves analyzing and solve different types of problems (Jonassen, 2000, 2011). Students need opportunities to engage in problem solving to further develop this skill (Herro, Quigley, Andrews, & Delacruz, 2017; Jonassen, 2011). Problem solving in the project-based classroom involves collaborating with others to solve problems that arise during the process of learning (Bell, 2010). Students need to practice the skill of problem solving by being challenged to solve different types of problems.

**Project-based learning:** “Project-based learning is an instructional model that is based in the constructivist approach to learning” (Tamim & Grant, 2013, p. 73). Project-based learning is a model that organizes learning around projects” (Thomas, 2000, p. 1). Project-based learning is active and driven by inquiry and student interest while covering content standards in deeper, more meaningful ways resulting in an artifact or project.

**Technology integration:** Technology integration is the process of incorporating technology in the learning environment. Technology integration can be implemented by substituting a digital tool for a task that was previously completed without the use of technology (Hilton, 2016a). When a task is transformed by technology it changes a task, giving students a new way to learn the content (Puentedura, 2013). Content and pedagogy need come first in the planning of lessons where technology is integrated. (Buckner & Kim, 2014; Dooley, Ellison, Welch, Allen, & Bauer, 2016). Technology integration allows
students to learn and share their learning in new ways that incorporate content and pedagogy.

**Technology integrated project-based learning:** Technology integrated project-based learning refers to the inclusion of technology resources within the project-based learning environment. It is important when integrating technology to consider content and pedagogy (Buckner & Kim, 2014; Dooley et al., 2016). Technology integration comes at the intersection of content, pedagogy, and technology.
CHAPTER 2

LITERATURE REVIEW

The purpose of this action research was to evaluate the implementation of technology integrated project-based learning to increase critical thinking skills in science for fourth grade students at Firebird Academy. The review of literature is guided by three research questions: 1) How does the implementation of technology integrated project-based learning affect the critical thinking skills of fourth grade students? 2) How does the implementation of technology integrated project-based learning affect the science content knowledge of fourth grade students? 3) How does the implementation of technology integrated project-based learning affect motivation to learn science content in fourth grade students?

The method I used for this literature review was comprehensive. I started with the broad concepts from my research questions: project-based learning, technology integration, critical thinking, and motivation. As I located resources for each of these, I made note of other keywords associated with the original search terms including: creative thinking, problem-based learning, questioning, digital portfolios, and reflection. Those keywords led to more narrowing of ideas and I eventually added several more keywords: inquiry-based learning, questioning techniques, electronic portfolios, and self-directed student learning. I limited my search to articles that had full text available, were peer-reviewed, and in the English language. I started my search with a limit to the last five years and extended the search to the last ten years. Some foundational research about
critical thinking, project-based learning, and problem solving required an extension beyond the ten-year time frame. As I continued my search through different articles, I became familiar with several authors and several authors were suggested (e.g., Blumenfeld, Krajcik, Grant, Marx, Ravitz, and Saunders-Stewart) that wrote about the topics in my research. I was then able to search for those authors and determine if they had any other useful resources. I used the reference section of articles as a source for locating additional resources associated with the keywords. I used *Education Source*, *ERIC*, *ProQuest Dissertations* as my primary source for searches.

The review of literature is organized into four main sections a) technology integration, b) project-based learning, c) critical thinking, and d) motivation.

The first section will start with the defining of technology integration and what it looks like in the K-12 classroom. Then it will take a look at different tools for integrating technology. Finally, this section will take a closer look at digital portfolios as a tool for curation and reflection within the scope of project-based learning.

The second section will focus on project-based learning, starting with a definition and the elements of project-based learning. A closer look at the elements of project-based learning will lead to a greater understanding of what is happening during project-based learning and the expectations of students and teachers. Perceptions of project-based learning is then examined through the eyes of teachers and students.

The focus of the third section is critical thinking. This section starts with a definition of critical thinking and what it looks like in the classroom. Then the connection of project-based learning and critical thinking is explored. Reflection and questioning as tools for developing and growing critical thinking skills is explored.
The final section is focused on motivation. Establishing the definition of motivation begins this section. Motivation is examined in the avenues of motivation for the purpose of grades or for the purpose of learning new information. Finally, the connection between motivation and student directed learning will be examined.

**Technology Integration**

Technology integration is not a new concept; technology advances in education have been implemented for many years. As new technologies are developed and introduced to the world of education, teachers are challenged to become researchers of what works best for their classroom. Technology can help to create an authentic real-world environment (Marx, Blumenfeld, Krajcik, & Soloway, 1997; Tamim & Grant, 2013). This section will look at the different aspects of technology integration through a) definition of technology integration, b) tools for technology integration, and c) digital portfolios.

**Definition of Technology Integration**

Defining technology integration involves looking through the lens of a K-12 classroom and the implications of technology advancements on classroom teachers. This section will explore the integration of technology, content, and pedagogy and its intersection with TPACK (Technological Pedagogical Content Knowledge). Finally, looking at how the technology is integrated to transform or enhance through SAMR (Substitution, Augmentation, Modification, Redefinition).

**Technology integration in the K-12 classroom.** Integrating technology in the classroom requires planning and thought to ensure that technology is used for learning and not in place of the learning. Dooley, Ellison, Welch, Allen, and Bauer (2014) posit
that technology integration is the use of mobile technologies to learn content where students are active participants not simply consumers of information. Buckner and Kim (2014) suggest technology needs to be connected to the pedagogy and content. Tondeur, van Braak, Ertmer, and Ottenbreit-Leftwich (2017) define technology integration as the use of technology to support 21st century teaching and learning. For the purpose of this study technology integration is where curricular content, pedagogy, and technology come together to enhance the learning experience and extend what is currently possible in the classroom.

Teachers’ beliefs, attitudes, and training are key components of technology integration (Dooley et al., 2016; Kim, Kim, Lee, Spector, & DeMeester, 2013; Petko, Prasse, & Cantieni, 2018). Teachers who have a positive perceptions about technology integration are more successful when bringing new technologies into the classroom (Kim et al., 2013; Minshew & Anderson, 2015). Teacher attitudes and beliefs can be impacted by outside influences, like availability of devices or by internal influences, like perceived abilities (Ertmer, Lane, Ross, & Woods, 1999; Kim et al., 2013; Petko et al., 2018). Teachers need proper training in the technology to teach students how to navigate technology resources (De Silva et al., 2016; Grant, 2016). Increased opportunity for teacher collaboration and technology training can help to create a positive attitude toward the integration of technology.

**TPACK – Technology Pedagogical Content Knowledge.** TPACK is the blending of content, pedagogy, and technology to create meaningful and effective learning experiences (Hilton, 2016b; Koehler, Mishra, & Cain, 2013). Although technology comes first in the name, the learning goals are the starting place for planning
learning experiences (J. Harris, Mishra, & Koehler, 2008; Wetzel & Marshall, 2011). For successful technology integration the technology use should not be separate from the content and pedagogy. The effective interaction between the three elements of TPACK can determine the success or failure of technology integration (Koehler et al., 2013).

Teachers depend on their knowledge of content to plan successful lessons and this approach can be carried over with relationship to technology integration. Technology Knowledge is always in a state of flux because technology is ever changing. This can be one drawback for teachers because learning about new technologies is time consuming (J. Harris et al., 2008; Minshew & Anderson, 2015). This can lead to technology integration at varying degrees in different classrooms because the amount of technology integration has a strong correlation to knowledge of technology (Kim et al., 2013; Minshew & Anderson, 2015). For example, one teacher may have an interest in technology, bringing in new applications for students to use in class. Other teachers at the same school or grade-level may be less proficient technologically and they become afraid to try new technologies with their students for fear they will not be able to carry out their lesson.

Content Knowledge refers to a teacher’s knowledge about the subject being taught. The amount of knowledge necessary to teach a subject varies at different levels, teachers need to be mindful of the depth and inquiry involved in adequately teaching to each level (J. Harris et al., 2008; Koehler et al., 2013). An example of this can be seen when looking at the concepts covered in a middle school classroom versus a high school classroom, biology in middle school looks similar but the depth of the subject is much greater in high school (Koehler et al., 2013). Another example is the use of the scientific method at an elementary level would be very basic with students learning the process and
conducting minor experiments but at the high school level students would be more deeply invested in analyzing results (Koehler et al., 2013). Teachers, regardless of their level need to be aware of the developmental needs and requirements of their students when deciding the depth of content to be covered.

Pedagogical Knowledge relates to the processes, practices, and methods teachers employ in their classroom and how those strategies relate to create a cohesive learning environment (Hilton, 2016b; Koehler et al., 2013). Teachers are trained in content and pedagogy in their teacher preparation programs. They are also tested in their content knowledge and pedagogy as they begin and continue their teaching practice. For example, a new teacher may be tested by her students as she navigates which teaching strategies work well with her students. Another teacher may search for new methods of inquiry and engagement in books or conferences. “A teacher with deep pedagogical knowledge understands how students construct knowledge and acquire skills in differentiated ways” (Harris et al., 2008, p. 397). Teachers become experts at the practices and strategies through training and classroom trials.

Technological Pedagogical Knowledge refers to how teaching and learning can change and grow when technology and pedagogy combine to change the way a classroom works (Koehler et al., 2013). Teachers must be willing to learn from students and teach students how to use devices in context of their classroom (Grant, 2016). Taking risks in the classroom involving technology integration requires support and training from professional development, peers, specialists, and administration (Kim et al., 2013; Minshew & Anderson, 2015).
Hilton (2016) conducted a study involving two social studies teachers integrating technology into their understanding of content and pedagogy. He found while they were experts in their content and understanding of pedagogy, they were limited in their technology knowledge (Hilton, 2016b). Choosing to limit their integration of technology to tasks that could easily be enhanced by the use of devices or applications (Hilton, 2016b). This illustrates another reason for the difference in the amount of technology integrated into classroom activities. Teachers who are not also experienced in technology knowledge can struggle with the integration of technology in their classrooms (De Silva et al., 2016; Dooley et al., 2016; Grant, 2016; J. Harris et al., 2008; Koehler et al., 2013).

**SAMR – Substitution, Augmentation, Modification, Redefinition.** SAMR works in two different ways to integrate technology either to enhance or transform the task (Hilton, 2016b; Puentedura, 2013). SAMR has two distinct levels enhancement and transformation. The first level, enhancement, includes substitution and augmentation. The second level, transformation, includes modification and redefinition.

**Substitution.** Substitution is a technology tool being used as a substitute for a tool currently used with no change (Puentedura, 2006). An example of this is using a word processing application to write an essay. The tool has changed from paper and pencil to a digital tool, but the assignment remains the same.

**Augmentation.** Puentedura (2013) explains augmentation taking place when you have direct tool substitution but there is a change in the way it is used. When students write with paper and pencil they have to go back and edit the paper for spelling and grammar errors and rewrite text if they want to make significant changes. When students use a word processor for writing a paper the word processing application offers tools like
spell check, grammar suggestions, and cut and paste tools for moving sections of text (Puente, 2006). The tool is a direct substitute for another tool but there is a functional change augmenting the task (Hilton, 2016b; Puentedura, 2006, 2013).

**Modification.** When the technology integration gives a task a redesign, modification takes place (Puentedura, 2006). An example of modification can be seen in a classroom where the teacher provides a science simulation or virtual lab for students to interact with and change variables altering the outcome of the experiment. Students are learning the standards they would have learned if the teacher had shown a diagram or video but the interaction with the elements involved in the experiment modifies the task (Hamilton, Rosenberg, & Akcaoglu, 2016; Puente, 2013).

**Redefinition.** When technology integration allows for the creation of new tasks, redefinition has taken place (Hamilton et al., 2016; Puentedura, 2013). An example of this comes from students collaborating on a project to share their knowledge of animal adaptations. Students worked together to visually represent the animal’s adaptations in a slide presentation with animations, transitions, video clips, and audio recorded by the students. Previously, students wrote a report to explain what they learned about their animal’s adaptation. This example, from my classroom, shows how the task was redefined to include more interaction with peers and technology as a medium for teaching others about their topic, redefining the task.

The intention of SAMR is to transform learning through technology integration (Chou, Block, & Jesness, 2012). SAMR shows there are different levels of technology integration and teachers may enter the world where tools and tasks come together in
different ways. There is no right or wrong way to integrate technology, there are just
different ways of enhancing or transforming.

One challenge with understanding SAMR is the limited amount of research that
has been conducted regarding the topic (Hamilton et al., 2016). Interpretation of each
stage of SAMR can be different depending on who is applying the definition. One teacher
may see a tool replacement as substitution while another teacher believes it is
augmentation (Hamilton et al., 2016). SAMR does not consider the context or elements
that effect the use of technology (Ertmer & Ottenbreit-Leftwich, 2010; Hamilton et al.,
2016). For example, teachers may have differing types of technology available or they
may not have support from administration to try new or innovative teaching techniques
involving technology (Ertmer & Ottenbreit-Leftwich, 2010).

**Tools for Technology Integration**

Students can research and learn, collaborate and communicate, and create and
share through the use of technology. Tools for technology integration range from
hardware to software choices. Hardware includes mobile devices (e.g., cell phones or
tables), laptops and Chromebooks, or desktop computers. Software can include programs
installed on a device, applications downloaded on mobile devices, and applications used
through the internet. These tools have many uses including production, collaboration, and
reflection.

**Tools for production.** Technology tools for production include tools that allow
students to create and produce new content or share what they have learned in a new and
different medium. Communication is one advantage of technology integration (Ahmed &
Nasser, 2015). Composing a video recording is a quick easy way for students to share
what they have learned with their peers and teacher. Digital portfolios showcase student work and reflection giving students the opportunity to look back on their work in a meaningful context (Fahey & Cronen, 2016; McCormick, 2017). Students also create products for synthesizing and sharing information. Designing a slide presentation to teach other classes about the importance of handwashing is an example of synthesizing and sharing information using technology. The slide presentation can then be shared with the school through a news program or emailing teachers to share with their classes. Creation products for retelling or summarizing information can take on many forms (e.g. PowerPoint, Keynote, Google Slides, Prezi) allowing students autonomy in how to produce their work (Ahmed & Nasser, 2015). There are many different forms of technology available for students to create artifacts of their learning which can lead to greater interest in learning and sharing.

**Tools for reflection.** Reflecting on learning can be done with the help of many different technology applications. Reflection is a powerful learning opportunity, given time to think and process students reach a deeper level of thinking (McCormick, 2017). Video applications for student voice, like Flipgrid, give students an opportunity to reflect and respond to questions or topics brought up in class (Green & Green, 2018). For example, students carrying out an experiment can record and share a reflection of the results, using Flipgrid. Sharing digital portfolios with the class as a whole gives students opportunity to gain feedback from peers and grow as a learning community (Fahey & Cronen, 2016). Digital portfolios also allow students to collect their work and look back at how they have progressed over the course of a specific activity or period of time. For example, students can upload assignments throughout the semester and then share their
work with families at a parent conference (McCormick, 2017). Digital portfolios used as a tool for curation and evaluation of one’s own work and progress, shifts the learning from the teacher to the student (McCormick, 2017).

**Digital Portfolios**

Digital portfolios are a tool used in many classrooms to gather artifacts of learning, reflect on student growth, and showcase exemplary work completed by students. The purpose of a portfolio has traditionally been to collect and display work for others to view. This purpose has shifted to a collection of work for the sake of evaluation of growth or individual accomplishment (McCormick, 2017). The research surrounding the use of digital portfolios has mainly focused on older students in middle grades, high school, or higher education (Cramer, 2009; McCormick, 2017). This study will look at elementary age students.

Digital portfolios are yet another meaningful way to integrate technology. Creating and maintaining digital portfolios engage students in synthesizing and presenting their work while learning valuable technology skills (Cramer, 2009). Digital portfolio creation can be in the form of a website (e.g. Google Sites or Weebly) where students can house creations, learning, thoughts, and reflections or an application called Seesaw.

Digital portfolios allow students to share thoughts, ideas, struggles, and thinking during the project as well as after the completion of the project (Fahey & Cronen, 2016; McCormick, 2017; Roberts, Maor, & Herrington, 2016). “Students become more aware of their learning and therefore are intrinsically motivated to challenge themselves in new and engaging ways through digital portfolios” (Fahey & Cronen, 2016, p. 136). Keeping
work in a digital portfolio allows the teacher and student to see the progress made during a project (Grant, 2002; McCormick, 2017). For example, McCormick (2017) found the teacher used digital portfolios as a tool to share student progress with parents. Allowing teacher and student to reflect on learning that took place improves both process and product (Fahey & Cronen, 2016; Roberts et al., 2016) Students edited submissions to digital portfolios showing their reflection on previous learning (Fahey & Cronen, 2016; McCormick, 2017). Digital portfolios give opportunities to improve and change the direction of learning through the process of reflection and analysis.

**Project-Based Learning**

Project-based learning is a constructivist approach where students are constructing knowledge as they learn about a topic and connect it to what they know and what they are learning. This section will look at the a) definition of project-based learning including the elements of project-based learning, b) project-based learning in the elementary classroom, c) the perceptions of students and teachers regarding project-based learning, and d) technology integration in project-based learning.

**Defining Project-Based Learning**

Project-based learning is based in the constructivist learning theory where students construct knowledge through active learning strategies. Students learn by doing while engaging in real-world related activities they may encounter in the future (Krajcik & Blumenfeld, 2006). In this section I will examine a) the definition of project-based learning, b) elements of project-based learning, and c) technology integration in project-based learning.
Project-based learning is an inquiry-based learning where students engage in learning new knowledge and skills through the process of inquiry (Martelli & Watson, 2016; Yancy, 2012). Project-based learning is active and driven by inquiry and student interest while covering content standards in deeper, more meaningful ways. In this study, project-based learning was operationalized as student-centered inquiry-based learning where students collaborate in an investigation and produce an artifact to show their learning and share with an audience.

**Elements of project-based learning.** The elements of project-based learning add different levels of learning for students. Thomas (2000) sets out five elements in project-based learning: projects should be central to content standards, focused on questions that drive the students to struggle with major concepts, involve constructivist investigation, driven by students and have real-world connections. Grant (2011) explains elements including: an introduction, a task, a process or investigation, resources, scaffolding mechanisms, collaboration, and reflection and transfer.

Project-based learning starts with a task or challenging question that is answered by actively searching to find answers and create knowledge (Grant, 2002; Martelli & Watson, 2016). Students are exposed to resources that include textbooks, websites, experts in the field of study, and trade books. Teachers may give a list of links to students or set up communication with an expert from the field. Collaboration may happen at this stage of the project, as well as later stages (Grant, 2002; Krajcik & Blumenfeld, 2006).

Another element of project-based learning is working toward an end result or project. Throughout the learning experience students will work toward the creation of a product that will be shared with others, a learning artifact (Krajcik & Blumenfeld, 2006).
Sharing products is an important part of project-based learning. As students prepare for their audiences, they connect what they have learned in a meaningful way and create lasting connections with the knowledge (Blumenfeld et al., 1991).

**Technology integration in project-based learning.** Technology can play an important role in the project-based learning classroom. Having multiple points of technology integration in one project can strengthen the effectiveness of the project (Stover, Kissel, Wood, & Putman, 2015). Students are using technology to research, create, display, and teach about the topic they are working with. Research in the form of a WebQuest or students looking at provided websites on a device gives students exposure to a greater amount of information to use in their learning (Grant, 2002; Kostaris, C; Sergis, S; Sampson, Demetrios, Giannakos, M, Pellicione, 2017; Krajcik & Blumenfeld, 2006). Another way technology might be integrated is for students to display their projects or findings through a website, slide presentation, or other visual format to inform others about what they learned (Krajcik & Blumenfeld, 2006; Wetzel & Marshall, 2011). The use of technology in the classroom and in project-based learning has a relationship to the work students will find in the real world (Blumenfeld et al., 1991; Grant & Branch, 2005). Project-based learning mirrors the work students will find when they leave school and prepares them to handle situations where they are expected to handle multiple elements of a project successfully.

**Project-Based Learning in the Elementary Classroom**

The use of technology should be participatory, students should learn content by actively using technology to participate in the learning (Buckner & Kim, 2014; Dooley et al., 2016). One of the benefits of a project-based learning environment is the many
learning outcomes. The first of those learning outcomes is depth of content, meaning students dive deeper into a subject rather than learning little about many different topics (Blumenfeld et al., 1991). With project-based learning the journey or process is as important as the product students prepare.

Project-based learning allows for differentiation in the classroom, where students have choice in how they learn (Bell, 2010). The traditional classroom offers little choice for students when the teacher is leading a whole group discussion chosen by the teacher or the standard curriculum (Dole, Bloom, & Kowalske, 2016). Having control or a voice in their own learning gives students renewed motivation for their learning, they are leading the learning instead of having a teacher give all the information for memorization and regurgitation (Bell, 2010; Dole et al., 2016; Grant, 2011). The teacher as facilitator has the opportunity to meet with students to inquire about choices the student is making, giving a chance to reach the student on a different level than traditional classroom styles.

Assessing Project-Based Learning

Assessment in project-based learning takes on many forms (Tamim & Grant, 2013). Assessment could include group work, group discussions, formative assessments, observations, digital portfolios, journals, self-reflections, or self-assessments (Bell, 2010; Grant & Branch, 2005; Krajcik & Blumenfeld, 2006). In the project-based learning environment assessment does not mean just one thing, students and teachers take many things into consideration throughout a project (e.g. collaboration, planning, thinking, problem solving, the artifact, and presentation).

Rubrics are one form of assessing student work in a project-based learning environment. A rubric can ensure students are all graded according to the same standards.
Having a rubric keeps the subjectivity of grading to a minimum and allows for more equitable grading procedures (Grant, 2002). Students benefit from having a rubric because the expectations of the learning experience are clear and written prior to the commencement of the project.

Another form for assessing student work is with the use of a digital portfolio. All of the work done during the project can be kept in a digital portfolio as artifacts of the process and learning that takes place. Examining and understanding student thinking and growth evidenced in the digital portfolio helps the teacher design future lessons and provide feedback to the student (Fahey & Cronen, 2016). The digital portfolio reflections of the student about his own work, the work of his group, and the work of other groups allows students to influence the process and make improvements upon their work (Fahey & Cronen, 2016). The digital portfolio is also a way for the teacher to assess the work of the student throughout the learning process, as well as at the end of the learning process (Grant, 2002). McCormick (2017), found kindergarten students spent time reflecting on their work as they paused to write about the artifacts they were posting in their digital portfolio. Another benefit of a digital portfolio is student self-analysis, students evaluate their own work and growth throughout the process (Fahey & Cronen, 2016; McCormick, 2017).

**Perception of Project-Based Learning**

Many different perceptions exist regarding the value of project-based learning. Students and teachers hold positive and negative perceptions associated with project-based learning. These perceptions can affect the outcome of learning in a project-based
learning environment. The results of these learning environments can depend on how students and teachers perceive how the benefits associate with the risks involved.

**Student perceptions of project-based learning.** Students enjoy working together with peers toward completion of a common goal (Savery, 2006). Collaboration on projects can lead to a deeper understanding because students have the opportunity to discuss and reflect on information they encounter (Krajcik et al., 1994). Another perceived benefit of project-based learning is the integration of technology. Features of technology integration decrease the challenges faced leaving students more opportunity to learn and connect with new information (Ravitz & Blazevski, 2014; Savery, 2006). For example, Ahmed and Nasser (2015), found the use of Edmodo increased the ability for students to collaborate with each other and the teacher creating more chances for interaction and learning. Students make strong connections to the content during project-based learning with the help of collaboration with peers and extended thinking about the topic being studied.

Grant (2011) found five themes emerged from a study conducted to assess student perceptions of project-based learning. These five themes can be used to describe the students process, project, and learning: a) internal influences, b) external influences, c) beliefs about projects, d) tools for technology-rich environments, and e) learning outcomes and products (Grant, 2011). The level of student engagement in different levels of the learning process can affect the outcome of student learning.

Internal and external influences can affect student motivation and self-efficacy. Persistence can play a factor in the successful completion of the learning and creation of an artifact (Grant, 2011). Teacher knowledge and management of the classroom can have
a correlation to how students perceive the process and learning (Holm, 2011). For example, teachers who choose technology that is easy to navigate help students build confidence and take risks with their learning (Ahmed & Nasser, 2015). Beliefs about projects are influenced by the amount of autonomy students have in choosing their topic (Grant, 2011). Students who participated in the creation of an artifact had differing results based on the expectations, restrictions, or logistics of the assignment (Grant & Branch, 2005).

Tools for technology-rich environments have an effect on the type of technology integrated by students. Grant (2011) found that students used technology for the production of their artifacts but not for learning more about their topic. The degree to which students in a school have access to technology will have influence on what students can achieve. Students feel control of their learning when they have the ability to choose the applications or technology used (Ahmed & Nasser, 2015). Grant and Branch (2005) posit the learning in project-based environments is not limited to the production of an artifact. The learning goes deeper, including the process and reflection, with the first four elements coming together to influence the learning outcomes and products (Grant, 2011). Student perception can influence their acceptance of the learning opportunity, their ability to collaborate, the depth of their learning, and their completion of the project,

**Teacher perceptions of project-based learning.** Teacher attitudes and beliefs can affect the success of learning in their classroom. The extent of pedagogical knowledge relating to project-based learning aspects can have a large effect on teacher willingness to participate in this type of teaching environment (Krajcik et al., 1994). Project-based learning involves risk because there is less control afforded to the teacher
and more autonomy given to students (Dole et al., 2016). Because of this shift, teachers need support and autonomy when leading project-based learning (Vega, 2011). Teachers need support to be free to have students learn in a different way. Feedback from students is needed to determine the level of learning taking place. Video reflections give teachers insight into student thinking and help to evaluate next steps in regards to student learning (Smith, 2016). Ravitz and Blazevski (2014) suggest teacher preparedness leads to more time on projects for students which leads to more opportunities for teachers to guide students. Teachers are the key to successful project-based learning, their willingness to step out of their comfort zone can lead to a deeper learning in their students.

In a study of teacher perceptions about project-based learning Grant and Tamim (2011) found three themes: 1) teachers define learning based on the possibilities for learning in their classroom, 2) teachers use of project-based learning varies of a continuum of the learning process, and 3) teachers embrace a student-centered approach. Teachers in this study enjoyed using the constructivist approach to use higher level thinking skills, increase student motivation, and assess student learning in new ways through authentic artifacts (Tamim & Grant, 2013).

**Critical Thinking**

Critical thinking involves many aspects of deeper thinking that aim to increase how students investigate, interact, and learn information and concepts. In this section I will examine a) the definition of critical thinking, b) critical thinking in the project-based learning classroom, c) reflection as a tool for developing critical thinking, and d) questioning strategies as a skill that strengthens critical thinking.
Defining Critical Thinking

Critical thinking has been defined and described in numerous ways. “Critical thinking is the art of analyzing and evaluating thinking with a view to improving it” (Paul & Elder, 2012, p. 4). Feely (1970) defines critical thinking as “the evaluation of evidence of argument based on acceptable standards for the purpose of accepting or rejecting a statement” (p. 2). Ennis (1985) defines critical thinking “as reasonable reflective thinking that is focused on deciding what to believe or do” (p. 45). For this study critical thinking is operationalized as analyzing information by asking questions, reflecting, and making sense of the information based on the context.

Through critical thinking students reflect on what they are learning and how they are learning to create a deeper understanding. Critical thinking is important for students to develop a deeper longer lasting understanding of content being studied. Critical thinking represents how to think rather than what to think: Students need to know how to think for themselves and make sense of situations or problems they encounter in the world (LaPoint-O’Brien, 2013). Metacognition is the thinking about one’s own thinking, helping the learner be aware of strengths and weaknesses to adjust to new or different tasks (Chick, 2012). Jin and Kim (2018) found that students working through a task use metacognitive strategies to solve problems. An example is shown in their study when students reflected on their own thinking and the thinking of their peers to solve problems involving circuits. When students think critically, they analyze and evaluate information, helping them better understand the information (Vitulli & Santoli, 2013). For example, students solving open-ended problems are tasked with using critical thinking to look at
the problem critically and approach the problem in a way that will find a solution (Leader & Middleton, 2004; Ravitz, 2010; The Partnership For 21st Century Skills, 2009).

Paul and Elder (2012) suggest critical thinkers are clear about the purpose for their thinking while questioning information, ideas, and opinions of others to make sense of what they are studying. For example, students tasked with considering how a circuit works questioned what was working, what was not working, suggested ideas, and questioned the ideas of others (Jin & Kim, 2018). Critical thinkers are able to think more effectively in different situations about different content areas (Elder & Paul, 2013).

Students who engage in critical thinking have done the work of learning by asking deep questions, reflected on the information they encounter, and made sense of information based on the context of their world (Elder & Paul, 2013; LaPoint-O’Brien, 2013; Paul & Elder, 2012; Vitulli & Santoli, 2013). The definition used for this research, that is critical thinking is analyzing information by asking questions, reflecting, and making sense of the information based on the context, will be a guide for evaluating student critical thinking within the context of using technology in project-based learning (Elder & Paul, 2013; LaPoint-O’Brien, 2013; Paul & Elder, 2012; Vitulli & Santoli, 2013).

**Impact of Project-Based Learning on Critical Thinking Skills**

Project-based learning is an active inquiry environment where students are actively engaging with content and process. These interactions with the content and process can cause students to use deeper thinking skills and allow them to make connections to content that are longer lasting (Siew & Mapeala, 2016). Students are asked to extend their thinking when working on a project. The activities and processes students complete when working through project-based learning experiences require
different skills than the traditional teacher centered where the teacher is at the front of the classroom delivering information to students (Smith, 2016). Project-based learning teamed with appropriate technology tools and support can help students to gain a better understanding of what they are learning (Tinnerman, Johnson, & Grimes, 2010). Project-based learning promotes critical thinking (Stolk & Harari, 2014). In the next section I will address a) reflection as a tool for developing critical thinking and b) questioning strategies to develop critical thinking.

Reflection as a tool for developing critical thinking. When students use reflection through written formats or videos they can see the development of their thinking throughout the learning process (Grant, 2011; Smith, 2016). Reflection is an important part of metacognition and critical thinking. Thinking about how we think can lead us to a better understanding of why we do the things we do (Jin & Kim, 2018). Reflection is a powerful tool that helps students create a connection to what is being learned and reflecting on the next steps in the learning process. For example, students who reflect on their learning process can make improvements to their learning in the future (McCormick, 2017). Reflection can also help connect the ideas of others to your own thoughts about a topic. For example, students using a digital portfolio to share their work with their peers, offered each other solutions to problems faced in their assignments (Fahey & Cronen, 2016). Reflection offers students time to step back and think about the work they have done, analyze their thought process, and find solutions they may have missed originally.

Questioning to develop critical thinking. Students lack questioning strategies and find it difficult to create probing questions, therefore, questioning strategies need to
be taught and developed (Buckner & Kim, 2014). Questions help students make sense of what they are learning (LaPoint-O’Brien, 2013). Creation of meaningful questions leads to analysis of information that is relevant to students’ interests (LaPoint-O’Brien, 2013; Rashid & Qaisar, 2016). Questioning skills are one of the most important parts of critical thinking. When a student can ask questions to dig deeper into a subject they are already thinking critically (Paul & Elder, 2008b). To ask the right questions students reflect upon the material and analyze the information. Once you understand the subject you can apply the questioning process to learn more. For example, a student who is just beginning to learn about a topic will ask different kinds of question than a student who has a base knowledge (Buckner & Kim, 2014; LaPoint-O’Brien, 2013). Asking the right questions leads to a deeper understanding and finding of more information.

**Motivation**

Motivation can be discussed in terms of intrinsic or extrinsic motivations. Motivation is difficult to measure. Motivation can be viewed from many different aspects. In this review, I will a) define motivation, b) look at academic motivation, and c) student self-efficacy.

**Definition of Motivation**

Motivation is the drive to want to do more and learn more (Glynn, Taasoobshirazi, & Brickman, 2009). It is an inner drive that makes a student want to continue working even when the work is difficult and strenuous (Shin, 2018). Intrinsic and extrinsic motivation can have an effect on student performance (Keller, 2017). Students need motivation to see that what they are striving for is worthwhile and meaningful to their present and their future. “Intrinsic motivation is defined as the doing
of an activity for its inherent satisfactions rather than for some separable consequence” (Ryan & Deci, 2000, p. 56). Extrinsic motivation is doing something for an expected reward or attainable outcome (Blumenfeld et al., 1991; Ryan & Deci, 2000). For example, students who are compelled by grades can be said to have extrinsic motivation.

**Motivation in the project-based learning classroom.** Project-based learning creates a new level of interest for students. An active learning environment creates higher engagement with a content topics and increases student drive for finding information (Cetin-Dindar, 2016). Choice and autonomy in regard to topic or artifact can determine the amount of motivation and interest students have in the project (Grant, 2002; Vedder-Weiss & Fortus, 2018). Choice in topic, methods, or product in a project-based learning activity can be highly motivating (Blumenfeld et al., 1991). Students become more motivated when they realize how science is related to the world outside of school (Cetin-Dindar, 2016; Keller, 2008; Krajcik & Blumenfeld, 2006). Engaging in projects connected to the local community can help students see the relevance of their learning. Engagement in project-based learning can motivate student to go the extra step when they may be feeling like quitting because they feel a sense of ownership in their projects (Tamim & Grant, 2013). They have a purpose for what they are doing, and the inner drive propels them to keep going. Student motivation increases as they become more responsible for what they are learning, how they are learning, and how they show their learning.

Decreased motivation to learn science has become an issue in education due to student perception and the increase in teacher centered teaching strategies (Fortus & Vedder-Weiss, 2014; Zeyer et al., 2013). For example, the decreased amount of time
devoted to science learning in many classrooms today gives students the impression that
science is not important for them to investigate (Zeyer et al., 2013). External influences
include grades, teachers, the classroom and available materials or technologies, logistics,
or time (Grant, 2011; Grant & Branch, 2005). Duration of the project is one factor Grant
found affected students’ motivations for the creation of their products. When students felt
the project had gone on too long, they lost their motivation.

**Motivation in a technology rich environment.** Technology itself can be a
motivator for some students. The use of technology to access resources can lead students
to new and interesting information (Krajcik & Blumenfeld, 2006). Technology options
available to students for sharing their artifact can create more excitement and motivate
students to put more effort into the end result (Grant, 2011; Krajcik & Blumenfeld,
2006). For example, when students produce artifacts for sharing with an audience they
consider what should be included (Grant, 2011). For example, students in my own
classroom created short slide presentations with audio to share knowledge they were
learning about the planets. One of the unexpected outcomes regarding student motivation
was the revision of their script multiple times before they started recording.

**Academic Motivation**

Students are often motivated by the promise of good grades (Grant, 2011). Grades
do not always equate to deeper learning. Students may be very good at school and know
how to navigate the expectations of assignments. This, external motivation, approval by
others or avoiding disapproval can lead the student to have success in their grades but it
does not mean they will retain the knowledge covered (Blumenfeld et al., 1991). For
example, motivation for the sake of grades discounts the reflective practices and critical
thinking required to have a closer relationship with the content knowledge (Glynn et al., 2009).

Motivation for the sake of learning new information requires a different kind of internal motivation (Blumenfeld et al., 1991). Students who are motivated by the acquisition of new knowledge have greater self-regulation and metacognitive skills leading to the development of deeper learning connections (Blumenfeld et al., 1991). Inquiry activities that are based on real-world problems with multiple solution paths are interesting and motivating to students and create motivation to stick with a task (Saunders-Stewart, Gyles, & Shore, 2012).

**Student as Self-Regulated Learners**

Social cognitive theory suggests that individuals are actively rather than passively shaping their environment (Bandura, 1994; Maddux, 1995). This theory can be applied to students in the classroom who are motivated to go beyond mere facts and take control of their learning. Student-directed learning leads to a path where increased motivation in learning happens (Blumenfeld et al., 1991; English & Kitsantas, 2013; Wurdiger, 2018). Although many topics or technologies may be motivating to students when implemented with project-based learning, it is important to remain focused on the content required by the standards (Krajcik & Blumenfeld, 2006). Self-regulated learners have a higher degree of motivation in relationship to learning and thinking about their learning (Mc Cormick, 2017). They have learned how to learn and take on challenging tasks oriented to give them a deeper understanding of the content. Self-regulated learners actively participate in their education which leads to a greater level of motivation (Mc Cormick, 2017). Self-
efficacy, or the believing in one’s abilities, is a determining factor in students’ motivation whether it is intrinsic or extrinsic (Bandura, 1998, 1994).

Summary

Project-based learning has a strong foundation in constructivism as an active learning experience (Bandura, 1994; Maddux, 1995). Constructivism is described as actively building knowledge by interacting with materials and content in meaningful situations (Cetin-Dindar, 2016; Krajcik & Blumenfeld, 2006; Martelli & Watson, 2016; Yancy, 2012). Teachers act as a guide while students navigate their way through information and tasks to create knowledge (Grant, 2002). Scaffolding is a benefit of the project-based learning experience, teachers design scaffolds to guide students through elements of their investigations further differentiating the learning environment (Grant, 2011; Tamim & Grant, 2013; Thomas, 2000).

A byproduct of project-based learning that is seen in classrooms but is difficult to measure is the growth of motivation in students who participate in these self-directed projects (Saunders-Stewart et al., 2012). Student autonomy can play a large role in the level of motivation seen. When students are intrinsically driven, they are learning for the sake of learning and growing not for the approval of someone else (Blumenfeld et al., 1991). Motivation is multifaceted and can be intrinsic or extrinsic.

Technology tools help to make project-based learning an interesting and motivating experience where students take a greater role in the responsibility for their learning (Tamim & Grant, 2013). Teachers play a large role in the integration of technology through their own perceptions of how technology can be used in the classroom (Ravitz & Blazevski, 2014). Integrating technology into a project-based
learning environment opens avenues for increased differentiation of products, new paths for learning, connections for critical thinking, and motivation to try something new.
CHAPTER 3

METHOD

The purpose of this action research was to evaluate the implementation of technology integrated project-based learning to increase critical thinking skills for fourth grade students at Firebird Academy. This research explored the following questions: How does the implementation of technology integrated project-based learning affect the critical thinking skills of fourth grade students? How does the implementation of technology integrated project-based learning affect the science content knowledge of fourth grade students? How does the implementation of technology integrated project-based learning affect the motivation to learn science content in fourth grade students?

Research Design

The purpose of my research, to determine the effect of technology integrated project-based learning on critical thinking skills, lends itself to action research. Action research aims to transform practice by changing what we do, say, think and how we reflect on our practice (Kemmis, 2009). Changing my practices based on observations and outcomes in my classroom contributes to growth in my practice and provides the best learning environment for my students. Action research is carried out by teachers for the purpose of improving instruction, classroom practices, or providing valuable information for themselves (Mertler, 2017). I am interested in this action research as a way to evaluate my classroom learning environment and affect the level of student learning in
my classroom and the classrooms of other teachers. As a practitioner-researcher, action research was the most logical choice for my research because I am a member of the learning community and thus a full participant (Mertler, 2017).

Manfra and Bullock (2014) point out the intimate nature of action research and its ability to bring new knowledge and understandings to the forefront that may not be observable by an outsider looking in. “Action research is research that is focused on a particular program, product, or method, usually in an applied setting, for the purpose of describing, improving, or estimating its effectiveness or worth” (Reeves & Oh, 2017, p. 326). My action research looked at the integration of technology into the project-based learning method and I applied the data collected to determine if students’ critical thinking and motivation are affected.

I chose a mixed-methods approach to my research because I was seeking both qualitative and quantitative data. Specifically, I used the triangulation mixed-methods design. I will collect quantitative and qualitative data at the same time and each was given an equal amount of emphasis (Mertler, 2017). I evaluated each type of data independently and then collaboratively to determine if the results are consistent. I chose to use a mixed methods approach in my action research because while my question has an open-ended nature, I was also interested in finding quantitative data to show student learning in the science content area. I used both qualitative and quantitative methods to create a complete picture of how technology integrated project-based learning effects the critical thinking skills of fourth-grade students.
Setting

This action research took place in my fourth-grade classroom at Firebird Academy. The content studied consists of the state standards for science, social studies, and English language arts. My students regularly used technology to research, write, and demonstrate learning. Throughout the year, we incorporate Microsoft Word and Microsoft OneNote within the learning environment. Students used a digital portfolio, Seesaw, to share their work with parents, the teacher, administration, and each other. As students completed work in their notebooks, workbooks, and digitally they have the option of sharing their work on Seesaw. Some assignments are created and completed using Seesaw exclusively. Seesaw is a platform where they demonstrate standards being learned in the classroom as formative assessment. Regular instruction in my classroom consists of students receiving a mini lesson for the standard being covered, small group work, and individual assignments. Students work on individual assignments while I work with a small group to address additional needs or provide enrichment.

A class set of laptops is checked out to the classroom on a permanent basis. Students have been taught proper handling of the laptops including signing on with their individual login information, how to properly save and store documents, and digital citizenship. The laptops were unavailable during school-wide testing because the computers are utilized for testing.

The physical environment was set up to allow students to move around as needed within the classroom. Desks were set up in groups of three to four students with students facing each other to work collaboratively. A large carpet area at the front of the classroom was used for class meetings and additional reading or working space as
needed. The front corner of the classroom was the reading corner; students used this location for silent reading or for meeting with other students to work in pairs. The opposite front corner had a two-seat computer desk with two laptops. There were two additional circle tables around the edge of the classroom that allowed students to collaborate with others not at their table group. A rectangular table was set up near the teacher’s desk area to allow for students to meet in small groups for additional instruction or interventions. This flexibility in seating allowed me to observe students interacting with each other and gives students an opportunity to interact with multiple students each day. Students enjoyed the flexibility to work around the room.

**Participants**

The majority of my students are middle class and have access to technology outside of school including tablets, cell phones, computers, and gaming systems. The class consisted of 23 students, 65% Caucasian, 13% Hispanic, 8% Asian, and 13% were classified as other. According to iReady reading data from students’ beginning of the year assessment, 52 percent of students were on or above grade-level and 48 percent were one grade-level below. Three students in the class were classified as Exceptional Student Education students with learning disabilities and are serviced by another teacher outside of the classroom for 120 minutes per week. One student received ESE services 60 minutes per week, attends occupational therapy 30 minutes per week, and participates in a social learning group 60 minutes per week. Seven students were female, and 16 students were male. Students in this class received all science content instruction from me, the teacher. As the classroom teacher, I was a participant researcher.
Innovation

The project-based learning experience “Habitats and Adaptations” took place during the Spring of 2019. In this study students participated in a technology integrated project-based learning experience to learn about animal habitats and adaptations, then present about their learning. The unit focused on an essential question: What elements are essential to an animal’s survival within the animal’s habitat? Students worked in collaborative teams to research, demonstrate, and present their learning through a project-based learning experience. The topics covered in this section included: a) background information, b) a description of the project, c) a table showing the correlation between the elements of project-based learning and each stage of the project, and d) a description of each stage of the project.

Background

Science instruction in the elementary classroom has a differing design based on teacher comfort level, expertise with content, and willingness to try new strategies (Krajcik et al., 1994). Traditional classrooms have teachers feeding information to students for memorization and retrieval for the sake of testing, but this does not promote understanding and deep knowledge of science concepts (Dole et al., 2016). An emphasis must be placed on the connection of active inquiry with critical thinking about the topic being learned (Marx et al., 1997). The active inquiry environment created by project-based learning increases the interaction between science content knowledge and critical thinking skills by encouraging students to deepen their thinking (Krajcik & Blumenfeld, 2006; Siew & Mapeala, 2016). Project-based learning was implemented because it increases student engagement and motivation for science learning (Chia Liu, Wang, Tan,
Ee, & Koh, 2009). Motivation is increased through student choice based on their interest, level of learning, and the production of an artifact to share their learning (Bell, 2010; Blumenfeld et al., 1991; Krajcik & Blumenfeld, 2006)

**Habitats and Adaptations Project**

As part of the “Habitats and Adaptations” project-based learning unit students chose an animal to research from a list of native state animals, created a model of the animal’s habitat, a presentation to educate others about the animal’s habitat and adaptations, and share what they created with an audience. Learning content and the essential question were based on state standards for fourth grade: Science heredity and interdependence standards, and English Language Arts writing, reading and speaking standards. Specifically, the project-based learning unit was aligned to the following fourth grade standards:

Big Idea 16 and 17 standards:

- SC.4.L.16.2 Explain that although characteristics of plants and animals are inherited, some characteristics can be affected by the environment.
- SC.4.L.16.3 Recognize that animal behaviors may be shaped by heredity and learning.
- SC.4.L.17.2 Explain that animals, including humans, cannot make their own food and that when animals eat plants or other animals, the energy stored in the food source is passed to them.
- SC.4.L.17.3 Trace the flow of energy from the Sun as it is transferred along the food chain through the producers to the consumers.
• SC.4.L.17.4 Recognize ways plants and animals, including humans, can impact the environment.

English Language Arts Standards:

• SL.2.4 Report on a topic or text, tell a story, or recount an experience in an organized manner, using appropriate facts and relevant, descriptive details to support main ideas or themes; speak clearly at an understandable pace.

• RI.3.9 Integrate information from two texts on the same topic in order to write or speak about the subject knowledgeably.

• W.3.7 Conduct short research projects that build knowledge through investigation of different aspects of a topic.

• W.3.8 Recall relevant information from experiences or gather relevant information from print and digital sources; take notes and categorize information and provide a list of sources.

Technology was incorporated into all aspects of this project (e.g., research on provided websites, creation of presentation, sharing of product). The project started with an introduction to the standards and essential question for the unit. Students then chose an animal to research, created their habitat and an educational presentation, and shared their project with an audience. Learning targets from science, language arts, and speaking standards were combined to create a habitat project for an animal in our gallery of native animal habitats.

Elements of the project were created using Grant's (2011) elements of project-based learning: introduction, defining a learning task, procedure for an investigation, suggested resources, scaffolding mechanisms, collaboration, and reflections and transfer
activities. Table 3.1 shows the relationship between each of the elements of project-based learning and the elements of this project. Each of the stages is further described in detail below.

*Table 3.1 Elements of project-based learning for habitats and adaptations project*

<table>
<thead>
<tr>
<th>Project-based learning element (Grant, 2011)</th>
<th>Stage 1 - Animals, Habitats, and Adaptations. (What does an animal need to survive? What about in our state?)</th>
<th>Stage 2 - Exploration - How do animals interact with their environments?</th>
<th>Stage 3 - Creation - Habitat &amp; Educational Presentation</th>
<th>Stage 4 - Sharing with an Audience</th>
</tr>
</thead>
</table>

**Introduction**

Students were introduced to the project using the essential question and corresponding standards:

What elements are essential to an animal’s survival within the animal’s habitat?

**Science Standards:**

- Plants and animals, including humans, interact with and depend upon each other and their environment to satisfy their basic needs.
- Identify behaviors that animals have naturally (inherit) and behaviors that animals learn.

**Language Arts Standards:**

- Report on a topic or text, tell a story, or recount an experience in an organized manner, using appropriate facts and relevant, descriptive details to support main ideas or themes; speak clearly at an understandable pace.
- Integrate information from two texts on the same topic in order to write or speak about the subject knowledgeably.
- Conduct short research projects that build knowledge through investigation of different aspects of a topic.
- Recall relevant information from experiences or gather relevant information from print and digital sources; take notes and categorize information and provide a list of sources.
<table>
<thead>
<tr>
<th>Project-based learning element (Grant, 2011)</th>
<th>Learning Task</th>
<th>Investigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage 1 - Animals, Habitats, and Adaptations. (What does an animal need to survive? What about in our state?)</td>
<td>Research and Identify the characteristics of an animal, its habitat, and any other unique qualities of the animal</td>
<td>Use the following questions to research what is needed to create a habitat and educational presentation for the animal. What does the animal need to survive in its environment? What specific adaptations does the animal have for the state environment? What features make the animal unique and interesting?</td>
</tr>
<tr>
<td>Stage 2 - Exploration - How do animals interact with their environments?</td>
<td>Use the information gathered to create an educational presentation about your animal, its habitat, adaptations, and other important facts.</td>
<td>present habitat, educational PowerPoint presentation, and information about animal (including answering questions)</td>
</tr>
<tr>
<td>Stage 3 - Creation - Habitat &amp; Educational Presentation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project-based learning element (Grant, 2011)</td>
<td>Stage 1 - Animals, Habitats, and Adaptations. (What does an animal need to survive? What about in our state?)</td>
<td>Stage 2 - Exploration-How do animals interact with their environments? Plan for habitat creation.</td>
</tr>
<tr>
<td>-----------------------------------------------</td>
<td>----------------------------------------------------------------------------------------------------------------</td>
<td>-----------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>Resources</strong></td>
<td>Links provided to students related to animals, habitats, and other relevant information.</td>
<td></td>
</tr>
<tr>
<td><strong>Scaffolding Mechanisms</strong></td>
<td>List of animals provided including general information about the animal</td>
<td>Graphic organizer for gathering information</td>
</tr>
<tr>
<td><strong>Collaboration</strong></td>
<td>Students share information and evaluate what information is necessary to create the habitat and educational presentation.</td>
<td>Students work together to create an animal habitat/exhibit and an educational PowerPoint presentation</td>
</tr>
<tr>
<td>Project-based learning element (Grant, 2011)</td>
<td>Stage 1 - Animals, Habitats, and Adaptations. (What does an animal need to survive? What about in our state?)</td>
<td>Stage 2 - Exploration - How do animals interact with their environments? Plan for habitat creation.</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Reflection and Transfer</td>
<td>Small group discussion</td>
<td>Small group discussion</td>
</tr>
<tr>
<td></td>
<td>Class discussion</td>
<td>Class discussion</td>
</tr>
<tr>
<td></td>
<td>Journal Reflection</td>
<td>Journal Reflection</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Plan for habitat</td>
</tr>
</tbody>
</table>

**Stage 1 - Animals, Habitats, and Adaptations.** As an entry event, students were shown a series of videos that showed different animals that live in our state. Next students participated in a discussion of the essential question, “What elements are essential to an animal’s survival within the animal’s habitat?” Students then brainstormed questions to guide their research (e.g. What does the animal need to survive in its environment? What specific adaptations does the animal have for the state environment? What features make the animal unique and interesting?). Using research and critical thinking skills, students evaluated the information about their animal, the animal’s habitat, needs of the animal, and adaptations that help it survive in the state environment. Students applied knowledge of life science standards to determine what their animal and its habitat requires.
Stage 2 - Exploration Plan for habitat creation. To create a plan for their animal and its habitats, students used information found in their research and the guiding question: How do native animals survive in their environment. Students created a drawing for their animal’s habitat including a list of elements that would naturally be in the animal’s habitat. Students discussed what they found in their research and continued to research to answer additional questions that arose from these group discussions. Once students completed their planning document, they met with the teacher to review the plan and explain what they included and reasoning behind different elements.

Stage 3 - Creation - Habitat & Educational Presentation. Stage 3 is divided into two parts for the creation of the learning artifacts: a) creation of animal habitat and b) creation of educational presentation.

Creation of Animal Habitat. Using their plan as a guide, students created their habitats from found materials provided by the teacher and students in the classroom. When creating the habitat students were provided a cardboard pizza box to transform into the habitat of their animal. Combining knowledge gained from their research, students made decisions about what to include in their habitat and the materials used to create each element. Students could create their animal from clay or provide a figurine from home to represent their animal. They used the box to represent and contain all elements within the habitat.

Creation of Educational Presentation. Students used PowerPoint to create an educational presentation for visitors to their exhibit. Their digital presentation taught about their animal and its unique qualities. Students collaborated as a group to determine important information and interesting facts to be included in their educational
presentation. The educational presentation included text and photos or illustrations to show an understanding of the animal and its habitat and adaptations. This step involved additional research to find the right photograph to represent exactly what students thought was the most important part of each slide. The educational presentation was shared with a kindergarten class, another fourth grade class, teachers and principals from the school, and parents who visited the exhibit.

Stage 4 - Sharing the Project. One kindergarten class, one fourth grade class, several teachers, two of the school’s principals, and most of the class parents visited the animal exhibit. When classes, parents, or administration visit, students shared their knowledge from the learning through their habitat, educational presentation, and answering questions about their animal and habitat.

Data Collection

I used four instruments to collect data for this study. I looked at the following sources for data to gain insight into the critical thinking skills, science content learning, and motivation to learn science content within a technology integrated project-based learning unit: 1) pre and post surveys, 2) critical thinking reflection prompts, 3) rubrics for artifacts, and 4) motivation to learn science survey. Table 3.2 shows the alignment between the research questions and each instrument. Each instrument is described in detail below.
Table 3.2 Alignment between data sources and research questions

<table>
<thead>
<tr>
<th>Research Question</th>
<th>Data Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. How does the implementation of technology integrated project-based learning affect the critical thinking skills of fourth grade students?</td>
<td>• Critical thinking prompts for student reflection journal</td>
</tr>
<tr>
<td>2. How does the implementation of technology integrated project-based learning affect the science content knowledge of fourth grade students?</td>
<td>• Pre and Post-objective assessment</td>
</tr>
<tr>
<td></td>
<td>• Assessment scores of projects (rubric)</td>
</tr>
<tr>
<td>3. How does the implementation of technology integrated project-based learning affect the motivation to learn science content in fourth grade students?</td>
<td>• Pre and post survey for student motivation for science learning</td>
</tr>
</tbody>
</table>

Pre and post survey. I used a survey (see Appendix B) to gather information about student motivation for science content learning. The survey used a five-point Likert scale. The survey will have two sections (a) intrinsic motivation and (b) grade motivation. Each section will have five questions for a total of ten questions. The survey is adapted from Glynn’s (2011) Science Motivation Questionnaire II (SMQ-II). Sample statements include the following items:

- Learning science is interesting.
- I am curious about discoveries in science.
- Scoring high on science tests and labs matters to me.
- It is important that I get an “A” in science.

Pre and post assessment. Students completed a pre- and postassessment on their content knowledge regarding habitats and adaptations. The science test was developed from the existing science curriculum and aligned with the state standards for habitats and adaptations (see Appendix C). The science content knowledge assessment will contain 18
items (see Appendix D). The instructional coach and colleagues at my school reviewed and made recommendations for inclusion of specific questions and content alignment to ensure validity. The data gathered gave me insight into gains made in the content area through the use of technology integrated project-based learning.

**Critical thinking reflection prompts.** Students answered critical thinking reflection prompts throughout the project-based learning unit. Students were given the critical thinking prompts at different points during the project-based learning unit based on the completion of different parts of the process. For example, prior to students starting their habitat creation they answered a prompt about how the questions they created helped them when carrying out their research. The prompts were given to students through the use of a Google Form for ease of collection and organization. Reflection on how students work through the problems of daily work lead to an internal dialogue that checks for clarity and understanding while deciding what is the best strategy to resolve situations that arise (Paul & Elder, 2008). The critical thinking prompts were designed in conjunction with another researcher measuring critical thinking skills in a student-centered learning environment. The prompts are aligned to Paul and Elder’s (2012) Elements of Thought (see Appendix E). Critical thinking prompt items are categorized in five sections:

- **Information**: All reasoning is based on data, information, and evidence.
- **Question**: All reasoning is an attempt to figure something out, to settle some question, to solve some problem.
- **Concepts**: All reasoning is expressed through and shaped by concepts and ideas.
- **Point of View**: All reasoning is done from some point of view.
• **Interpretation and Inference**: All reasoning contains inferences or interpretations by which we draw conclusions and give meaning to data.

**Artifact assessment scores.** Student artifacts will be scored using a rubric based on the science content standards. The rubric evaluated elements of the project including: (a) Demonstrate understanding of animal adaptations based on environmental changes, heredity, and learning, (b) Vocabulary related to adaptations, environmental changes, heredity, and learning is used in the presentation, (c) Describe how an animal’s habitat is affected by humans and other animals, (d) Describe how an animal gets energy from the resources in its habitat (flow of energy), and (e) Vocabulary related to habitats, food chains, and environmental changes is used in the presentation. The scale 3-exceeds expectation, 2-meets expectations, and 1-below expectations will be used, and written feedback will be provided (see Appendix F). The instructional coach and colleagues at my grade-level reviewed and made recommendations for standard and content alignment to ensure validity. Artifacts were scored to determine the level of learning within the area of adaptations and habitats.

**Data Analysis**

For each research question, a quantitative and qualitative method of data collection was utilized to triangulate the data and produce the most reliable findings (Creswell, 2014). Table 3.3 shows the alignment between research questions, data sources, and data analysis. A full description of the data analyses is presented in Chapter 4.
Table 3.3 Research Questions, data sources, data analysis alignment

<table>
<thead>
<tr>
<th>Research Questions</th>
<th>Data Sources</th>
<th>Data Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. How does the implementation of a technology integrated project-based learning unit affect the critical thinking skills of fourth grade students?</td>
<td>Critical thinking prompts for student reflection journal</td>
<td>Inductive analysis</td>
</tr>
<tr>
<td>2. How does the implementation of technology integrated project-based learning affect the science content knowledge of fourth grade students?</td>
<td>Pre- and Post-objective assessment, Assessment scores of project (rubrics)</td>
<td>Paired sample t-test, Descriptive statistics</td>
</tr>
<tr>
<td>3. How does the implementation of technology integrated project-based learning affect motivation to learn science content in fourth grade students?</td>
<td>Pre and post motivation to learn science survey</td>
<td>Wilcoxon Signed-ranks test, Descriptive statistics</td>
</tr>
</tbody>
</table>

Procedures and Timeline

The procedures for this research are categorized into four phases. Table 3.4 details the expectation and timeframe for each stage. A detailed description of each phase follows the table.

Table 3.4 Timeline of Data Collection and Data Analysis

<table>
<thead>
<tr>
<th>Phase</th>
<th>Expectation</th>
<th>Time Frame</th>
</tr>
</thead>
</table>
| Phase 1 | 1. Consent and assent forms completed  
2. Student Motivation Survey completed  
3. Pre-Assessment completed | 1 week     |
| Phase 2 | 1. Student Reflection Journal  
2. Student Motivation Survey completed | 6 weeks    |
| Phase 3 | 1. Post-Assessment completed  
2. Assessment of Artifact | 1 week     |
| Phase 4 | 1. Analysis of Student Reflection Journal  
2. Analysis of Student Motivation Survey  
3. Analysis of Pre and Post Assessment | 4 weeks    |
Phase 1

Phase 1, consent and assent forms were completed. Students completed a student motivation survey and pre-assessment prior to the start of the project-based learning experience.

Phase 2

Phase 2 began when students began to work through the project-based learning experience. Students were given a critical thinking prompt to answer five times during the learning experience. Students completed a second motivation survey at the end of phase 2.

Phase 3

Phase 3 marked the end of the project-based learning experience with the student’s completion of the post assessment. Student artifacts were assessed by the teacher during this phase.

Phase 4

Student critical thinking reflection prompts were examined and coded to look for emergent patterns and key themes. Student survey data was analyzed for patterns in student motivation toward science content learning. Pre- and postassessment data was analyzed for student growth in science content learning.

Rigor and Trustworthiness

In addition to the validity and reliability measures of the quantitative data collection measures, the following four research techniques were employed to assure rigor and trustworthiness of the qualitative data and findings: triangulation, an audit trail, member checking, and peer debriefing. Each technique is described below.
**Triangulation**

Triangulation is the process of using multiple sources of data to verify the consistency of findings within research (Mertler, 2017). Triangulation of data allows for a comprehensive understanding of findings and strengthens a study by combining methods (Welch & Patton, 1992). In this study, methodological triangulation occurred through the use of quantitative and qualitative data collection methods. Methodological triangulation further occurred with the use of two different forms of quantitative data collection methods (pre- and postassessment and surveys) and two different forms of qualitative data collection methods (descriptive statistics from the artifact rubric and reflection prompts).

**Member Checking**

Member checking is a form of participant validation in which research findings are shared with those who participated in the experience for evaluation of accuracy (Birt, Scott, Cavers, Campbell, & Walter, 2016). Member checking happened during a debriefing session with students after student reflection journals had been analyzed. Analysis of the student reflection journals including patterns and themes was shared with students to demonstrate their thinking during the project-based learning experience. I showed students examples of what critical thinking looked like during active learning and how the reflection journals were interpreted using patterns of student thinking.

**Peer Debriefing**

Peer debriefing adds to the rigor and trustworthiness by involving an external source who will question methods, analysis, and interpretation of the research to help clarify and move the research process forward (Mertler, 2017). Debriefing sessions
between the researcher and someone in a superior position allows the researcher to further develop interpretations and identify flaws in the process (Shenton, 2004). My dissertation chair and committee will be a sounding board for ideas, analysis, and interpretations throughout the research study.

**Audit Trail**

A researcher makes notes during all phases of the data collection process including notes during interviews, observations, and analysis. “The reflective commentary may also be used to record the researcher’s initial impressions of each data collection session, patterns appearing to emerge in the data collected and theories generated” (Shenton, 2004, p. 68). The notes or memos become the audit trail for the researcher, providing evidence of the thought process and analysis, and adding to the rigor of the research. Keeping a journal of my thoughts and observations was a vital part of my research and provided visual proof of my thought process. It allowed me to keep track of what I see, how my thinking changed, how the analysis developed, and my interpretation of events. These notes served as a reminder of each part of the data collection process further strengthening my research.

**Plan for Sharing and Communicating Findings**

Colleagues, students, parents, and school administration are all stakeholders in this research. Each stakeholder will be given a copy of the results of my research and recommendations for next steps. Sharing the results with the participants during an informational session created a greater awareness of their own ability to think critically as they determined if the results are an accurate description of what took place in the classroom (Creswell, 2014; Mertler, 2017). I shared the results of my research with
administration and at the school level through one of our monthly professional
development sessions. At the professional development session, I included findings about
the implementation of technology integrated project-based learning, the process of
integrating technology into project-based learning, and student progress during the
project. Future plans include sharing at local and regional educational technology
conferences. To protect the identities and ensure confidentiality of participants I will use
pseudonyms in the write up. Any personalizing or identifying information will be
scrubbed in order to protect individual student’s identities.
CHAPTER 4

ANALYSIS AND FINDINGS

This purpose of this action research was to describe the impact of technology integrated project-based learning on critical thinking and motivation to learn science fourth grade students. Both quantitative and qualitative data were collected to answer the following questions: (1) How does the implementation of technology integrated project-based learning affect the critical thinking skills of fourth grade students? (2) How does the implementation of technology integrated project-based affect science content knowledge in fourth grade students? (3) How does the implementation of technology integrated project-based learning affect motivation to learn science content in fourth grade students? This chapter will begin with analysis and findings of the three quantitative sources followed by analysis of the three qualitative sources.

Quantitative Analysis and Findings

This study included three quantitative data sources. The three data sources include 1) Science Content Knowledge Assessment, 2) Rubric Scores, and 3) Motivation to Learn Science Survey. This section will include the results of each assessment; include descriptive statistics, and levels of significance.

Science Content Knowledge Assessment

The Science Content Knowledge Assessment was developed from the existing science curriculum and aligned with the state standards for habitats and adaptations. The Science Content Knowledge Assessment contained 18 items. The school instructional
coach, and four colleagues at my school reviewed the assessment for content validity. The reliability of the instrument was tested with the posttest data \((n = 25)\) for the 18 items. Item 18 had a variance equal to zero, so it was removed from the reliability analysis. The Cronbach’s alpha for the remaining 17 items on the instrument was 0.58, so interpretations should be tentative with this level of reliability (DeVellis, 2003).

Descriptive statistics for the Science Content Knowledge Assessment scores are recorded in Tables 4.1 and 4.2. The proportion of each item answered correctly is reported in Table 4.2. The mean total number of correct items is reported in Table 4.1. The maximum score was 18. The pretest scores ranged from 6 to 16 with a mean of 10.24 and a standard deviation of 2.57. The posttest scores ranged from 6 to 16 with a mean of 12.76 and a standard deviation of 2.59. Question 13 had a low score on both the pretest and posttest. Question 11 had the lowest score on both the pretest and posttest. Question Eight had the highest increase in score from 28% to 80%.

<table>
<thead>
<tr>
<th>Items</th>
<th>Percent Correct Pretest</th>
<th>Percent Correct Posttest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1: Animal Adaptations and Habitats</td>
<td>88%</td>
<td>88%</td>
</tr>
<tr>
<td>Q2: Animal Adaptations and Habitats</td>
<td>84%</td>
<td>80%</td>
</tr>
<tr>
<td>Q3: Animal Adaptations and Habitats</td>
<td>72%</td>
<td>72%</td>
</tr>
<tr>
<td>Q4: Animal Adaptations and Habitats</td>
<td>36%</td>
<td>52%</td>
</tr>
<tr>
<td>Q5: Animal Adaptations and Habitats</td>
<td>72%</td>
<td>80%</td>
</tr>
<tr>
<td>Q6: Animal Adaptations and Habitats</td>
<td>56%</td>
<td>60%</td>
</tr>
<tr>
<td>Q7: Animal Adaptations and Habitats</td>
<td>88%</td>
<td>92%</td>
</tr>
<tr>
<td>Q8: Animal Adaptations</td>
<td>28%</td>
<td>80%</td>
</tr>
</tbody>
</table>

Table 4.1 Descriptive Statistics for Science Content Knowledge Assessment \((n = 25)\)

<table>
<thead>
<tr>
<th></th>
<th>Pretest M</th>
<th>Pretest SD</th>
<th>Posttest M</th>
<th>Posttest SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Scores</td>
<td>10.24</td>
<td>2.57</td>
<td>12.76</td>
<td>2.59</td>
</tr>
</tbody>
</table>

Table 4.2 Proportion of Items Correct for Science Content Knowledge Assessment
\((n = 25)\)
A paired-samples t-test was conducted to compare pretest and posttest means for the Science Content Knowledge Assessment. There was a significant difference in the scores for pretest \((M = 10.24, SD = 2.57)\) and posttest \((M = 12.76, SD = 2.59)\) means, \(t(24) = 5.93, p < .001, d=1.19\). Students on average scored significantly higher on the posttest than the pretest.

**Rubric Scores**

The project rubric scored students on life science standards across five criteria. The following scale was used for each criterion: 3: Exceeds expectations, 2: Meets expectations, and 1: Below expectations. The maximum score was 15. In addition, written feedback was provided. The district science coach, my school instructional coach, and four colleagues at my grade level reviewed and made recommendations for standard and content alignment to ensure content validity. The reliability of the instrument was tested with the item data \((n = 26)\) for the 5 items. The Cronbach’s alpha for the 5 items on the instrument was 0.74, internal consistency is respectable with this level of reliability. I evaluated the projects and assigned the scores for all of the rubric criteria.

<table>
<thead>
<tr>
<th>Items</th>
<th>Percent Correct Pretest</th>
<th>Percent Correct Posttest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q9: Animal Adaptations</td>
<td>56%</td>
<td>88%</td>
</tr>
<tr>
<td>Q10: Animal Adaptations</td>
<td>76%</td>
<td>92%</td>
</tr>
<tr>
<td>Q11: Animal Adaptations</td>
<td>20%</td>
<td>28%</td>
</tr>
<tr>
<td>Q12: Animal Adaptations</td>
<td>56%</td>
<td>60%</td>
</tr>
<tr>
<td>Q13: Food Chain</td>
<td>36%</td>
<td>36%</td>
</tr>
<tr>
<td>Q14: Food Chain</td>
<td>36%</td>
<td>44%</td>
</tr>
<tr>
<td>Q15: Flow of Energy</td>
<td>76%</td>
<td>96%</td>
</tr>
<tr>
<td>Q16: Flow of Energy</td>
<td>32%</td>
<td>64%</td>
</tr>
<tr>
<td>Q17: Impact on Habitats</td>
<td>36%</td>
<td>68%</td>
</tr>
<tr>
<td>Q18: Impact on Habitats</td>
<td>76%</td>
<td>100%</td>
</tr>
</tbody>
</table>
Descriptive statistics for the project rubric scores are recorded in Table 4.3. The total rubric scores ranged from 7 to 13 with a mean of 10.19 and a standard deviation of 1.72. Criteria three in the rubric, describe how an animal’s habitat is affected by humans and other invasive species, has the greatest variation. Criteria two, demonstrate understanding of animal adaptations based on environmental changes, heredity, and learning, has the highest performance. Criteria five, vocabulary related to habitats and food chains is used in the presentation, has the lowest performance.

Table 4.3 *Descriptive Statistics for Project Rubric Scores (n = 26)*

<table>
<thead>
<tr>
<th>Rubric Criteria</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demonstrate understanding of animal adaptations based on environmental changes, heredity, and learning.</td>
<td>2.43</td>
<td>0.50</td>
</tr>
<tr>
<td>Vocabulary related to adaptations, environmental changes, heredity, and learning is used in the presentation.</td>
<td>2.23</td>
<td>0.43</td>
</tr>
<tr>
<td>Describe how an animal’s habitat is affected by humans and other invasive species.</td>
<td>2.12</td>
<td>0.77</td>
</tr>
<tr>
<td>Describe how an animal gets energy from the resources in its habitat.</td>
<td>1.73</td>
<td>0.45</td>
</tr>
<tr>
<td>Vocabulary related to habitats and food chains is used in the presentation.</td>
<td>1.69</td>
<td>0.62</td>
</tr>
<tr>
<td>Total Scores</td>
<td>10.19</td>
<td>1.72</td>
</tr>
</tbody>
</table>

**Student Motivation for Science Survey**

Glynn’s (2011) SMQ-II is an established survey with two subscales: (a) intrinsic motivation and (b) grade motivation. Each section has five items for a total of 10 items. The original instrument used a frequency five-level scale of “Never” to “Always.” In this implementation, I rescaled the responses to use a five-point Likert-type scale of 1:Strongly Disagree to 5:Strongly Agree. The reliability of the intrinsic motivation subscale was tested with the posttest data (n = 24) for the five items. The Cronbach's
alpha for the intrinsic motivation was .77. The reliability of the grade motivation subscale was tested with the posttest data ($n = 24$) for the five items. The Cronbach's alpha for the grade motivation was .79. Both sections were found to be reliable (DeVellis, 2003).

Descriptive statistics for the intrinsic motivation for science survey subscale are presented in Table 4.4. The five items’ scores were averaged for each participant. The pretest scores had a range of 2.4 to 4.4 with a mean of 3.52 and a standard deviation of 0.62. The median for the pretest was 3.70. The posttest survey scores had a range of 2.4 to 4.4 with a mean of 3.71 and a standard deviation of 0.64. The median for the posttest was 3.90.

Table 4.4 Descriptive Statistics for Intrinsic Motivation for Science Survey ($n = 24$)

<table>
<thead>
<tr>
<th></th>
<th>M</th>
<th>SD</th>
<th>Mdn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre Intrinsic</td>
<td>3.52</td>
<td>0.62</td>
<td>3.70</td>
</tr>
<tr>
<td>Post Intrinsic</td>
<td>3.71</td>
<td>0.64</td>
<td>3.90</td>
</tr>
</tbody>
</table>

Descriptive statistics for grade motivation for science survey subscale are presented in Table 4.5. The pretest scores had a range of 2.0 to 5.0 mean of 4.19 and a standard deviation of 0.65. The median for the pretest was 4.20. The posttest survey scores had a range of 2.2 to 5.0 with a mean of 3.90 and a standard deviation of 0.73. The median for the posttest was 4.10.

Table 4.5 Descriptive Statistics for Grade Motivation for Science Survey ($n = 24$)

<table>
<thead>
<tr>
<th></th>
<th>M</th>
<th>SD</th>
<th>Mdn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre Grade</td>
<td>4.19</td>
<td>0.65</td>
<td>4.20</td>
</tr>
<tr>
<td>Post Grade</td>
<td>3.90</td>
<td>0.73</td>
<td>4.10</td>
</tr>
</tbody>
</table>
Paired-samples $t$-tests were planned for comparing the pretest and posttest data for the two subscales. However, after tests of normality (i.e., Shapiro-Wilk), the data sets were determined to be non-normal data. Therefore, non-parametric Wilcoxon Signed-ranks tests were conducted for each pair (i.e., intrinsic motivation, grade motivation) of pre-post data. A Wilcoxon Signed-ranks test compared pretest and posttest scores for intrinsic motivation. The output indicated that posttest scores ($Mdn = 3.90$) were not significantly higher than pretest scores ($Mdn = 3.70$), $Z = 1.95$, $p = .052$. This test approached statistical significance. A second Wilcoxon Signed-ranks test compared pretest and posttest scores for the grade motivation subscale. The output indicated that posttest scores ($Mdn = 4.10$) were not significantly higher than pretest scores ($Mdn = 4.20$), $Z = 1.84$, $p = .066$.

**Qualitative Analysis and Findings**

Student reflections were collected throughout the learning process through a series of critical thinking prompts. There was a total of seven critical thinking prompts during the course of the project-based learning experience. A total of 166 critical thinking prompt responses from 26 students were collected during the course of the project. In addition, there were 57 entries in the research and observation notes collected throughout the process of the study. Through the analysis of this data 3 themes emerged: a) growing critical thinking skills through project-based learning, b) co-creating artifacts, and c) reaching an authentic audience.
Table 4.6 *Summary of Qualitative Data Sources.*

<table>
<thead>
<tr>
<th>Types of Qualitative Data Sources</th>
<th>Number</th>
<th>Total Codes Applied</th>
</tr>
</thead>
<tbody>
<tr>
<td>Researcher Notes and Observations</td>
<td>1</td>
<td>191</td>
</tr>
<tr>
<td>Student Critical Thinking Prompt Reflections</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1a. Questioning</td>
<td>23</td>
<td>37</td>
</tr>
<tr>
<td>1b. Questioning</td>
<td>23</td>
<td>38</td>
</tr>
<tr>
<td>2a. Concepts</td>
<td>25</td>
<td>47</td>
</tr>
<tr>
<td>2b. Concepts</td>
<td>25</td>
<td>43</td>
</tr>
<tr>
<td>3. Informed planning</td>
<td>23</td>
<td>43</td>
</tr>
<tr>
<td>4. Problem-Solving</td>
<td>21</td>
<td>32</td>
</tr>
<tr>
<td>5. Problem-Solving</td>
<td>25</td>
<td>35</td>
</tr>
<tr>
<td>Totals</td>
<td>166</td>
<td>466</td>
</tr>
</tbody>
</table>

**Analysis of Qualitative Data**

The data were collected from students through a Google Form which allowed me to put the responses in a Google Sheets spreadsheet and download it to my computer as a Microsoft Excel spreadsheet. Each student’s responses were gathered and organized in a Google Sheet spreadsheet. I then organized them in a Microsoft Word document by student and further by prompt. I then copied the information and pasted it into the Delve Tool (2019) application and called them Journal Prompts. For my researcher notes and observations I used Google Keep recording daily my observations and feelings about the process. I then copied my notes from Google Keep and pasted them into the Delve Tool application and called them Researcher Notes.

Delve (2019), an online coding tool, was used to analyze the qualitative data. Analysis began with structural coding to categorize student responses and thinking (Saldana, 2016). When analyzing the journal prompt data, I went prompt by prompt and
sentence by sentence. When I analyzed the research notes I went day by day and sentence by sentence.

I started with structural coding to organize my data (Figure 4.1). I coded student reflection prompts by the prompt number, two of the critical thinking prompts had two parts which I distinguished with an a and b in the name (CTP1a, CTP1b), the other critical thinking prompts had only one part (CTP3, CTP4). I coded all critical thinking prompt data by the student (S01, S02) it belonged to. I assigned codes to my research notes and observations by the number of the day in our study (Day 01, Day 02). The process of structural coding helped me become more familiar with the body of data.

![Figure 4.1 Structural Codes](image)

**Figure 4.1 Structural Codes**

Initial coding then continued by analyzing data further using process coding for keywords and phrases related to actions students took during the process (Saldana, 2016). I assigned process codes according to the action being carried out by the student, *collaborating, researching, planning, discussing* (Figure 4.2). These codes came from...
student responses to the critical thinking prompts and the observations I made in class. For example, one student stated, “We all agreed on what information to use and what information was most important.” I coded this statement as *collaborating* because it showed how students worked together within their group to reach a decision about what information to use and how it was important to their task. Another code assigned during this process was *problem solving* because it is closely related to critical thinking, which is a major topic of this study. An example of the application of this code came from a student’s critical thinking prompt response when he stated, “We had one problem it was that we did not know if manatee lived in salt water or fresh water so we looked up more stuff about the manatee and we saw that they live in fresh water.” This step added to the organization of data allowing me to relate the actions back to the project-based learning process. The codes that emerged were a) researching, b) thinking, c) collaborating, d) planning, e) creating, f) questioning, g) using information, h) gathering information, i) categorizing, and j) reflecting.

*Figure 4.2 Process Codes*
Next, I coded my researcher notes using in vivo coding (Saldana, 2016). Some of the codes used were motivation, group dynamics, assessment, difficulties, and technology use. An example of these codes for assessment is my observation on Day 8. I wrote, “We discussed what they have included to this point and if they were lacking important information.” This is one form of assessment in the project-based learning process and one way I evaluated the next steps for myself and students in the learning. This was later coded as reflection and included with teacher reflection. Another example is a statement made on Day 13. I wrote, “I am having a hard time with the critical thinking prompts because I have seen groups have some great discussions but trying to get them to put down on paper the process they used is very difficult.” The code applied was difficulties, which referred to the difficulties that arose during the process of project-based learning. Examining my research notes and observations helped me to make sense of the process of project-based learning from my perspective and reflect on the outcomes of the learning.

Second cycle coding brings a better understanding of the data by reorganizing and merging codes based on similarities (Saldana, 2016). Further analysis of these process codes showed a connection to my first research question related to critical thinking. Through pattern coding (Saldana, 2016), I organized the existing codes into the categories of a) concepts, b) information, c) purpose, d) questions, and e) reflection. I began by looking for codes that connected to the steps of project-based learning and critical thinking specifically looking for how students used critical thinking throughout the process of learning. This led me to look at codes tied to the concepts of critical thinking including a) questioning, b) concepts or conceptual understanding, c) information or gathering and using information, and d) reflection or reflecting on
learning. I also included the code, *purpose*, because students thought deeply about who their audience would be when planning and presenting their learning.

**Figure 4.3 Combining Codes**

*Related to Critical Thinking*

I needed to see all the codes in one place, so I printed the codes and decided that I needed to write the codes in a list to see how the information fit together (Figure 4.4). I did not include the individual structural codes because they were only telling the information about students, days, and prompt. This information did not inform my research because it did not tell about how the learning affected the students or the process. After writing the codes I was able to see how some codes belonged together and I began to see the picture of my data.
Next, I grouped the codes together how I thought they fit (Figure 4.5). I put brainstorming, questioning, researching, thinking, discussing, categories, categorizing, gathering information, and using information together. I then took out researching because it was part of gathering information and put in reflecting because all of these were parts of the project-based learning experience and were related to critical thinking during the process. I grouped researching, planning, compromising, problem solving, and collaborating together as part of the creation process. Finally, I grouped researching, purpose, student interest, and motivation together as part of what motivated students during the process of learning. I eventually added student reactions as part of this final grouping.
Looking at the information in this visual format allowed me to identify the emerging themes. I continued by creating a flow chart for each of the themes. Figure 4.6 shows the flow from code to concept to the theme, growing critical thinking skills through project-based learning. Figure 4.7 shows the flow from code to concept to the theme, co-creating artifacts. Figure 4.8 shows the flow from code to concept to the theme, reaching an authentic audience.
Figure 4.6 Growing Critical Thinking Skills Through Project-Based Learning

Figure 4.7 Co-Creating Artifacts

Figure 4.8 Reaching an Authentic Audience
Coding of critical thinking prompt responses started with looking for specific actions taken by students in the process of learning. I looked for actions related to carrying out the tasks in the project-based learning process. Specifically, I considered actions like questioning, researching, collaborating, discussing, planning, thinking, creating, and problem solving. Questioning and researching included students’ use of resources to examine and collect information. Collaborating encompasses any tasks students completed with the help or cooperation of their group mates. Problem solving required students to work to solve issues that arose throughout the process, either with their team or alone. Table 4.7 shows the elements of critical thinking examined in student prompts and the number of codes applied to each.

Table 4.7 Codes from critical thinking prompts.

<table>
<thead>
<tr>
<th>Elements of Critical Thinking Prompts</th>
<th>Number of Codes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Questioning</td>
<td>32</td>
</tr>
<tr>
<td>Conceptual understanding</td>
<td>37</td>
</tr>
<tr>
<td>Research/Gathering Information</td>
<td>49</td>
</tr>
<tr>
<td>Planning/using information</td>
<td>47</td>
</tr>
<tr>
<td>Problem solving</td>
<td>49</td>
</tr>
<tr>
<td>Collaborating</td>
<td>81</td>
</tr>
<tr>
<td>Reflection/Purpose for Learning</td>
<td>17</td>
</tr>
<tr>
<td>Totals</td>
<td>312</td>
</tr>
</tbody>
</table>

Researcher notes and observations are important to the process of action research (Mertler, 2017). To analyze the data presented in my notes and observations from each day of the learning process I looked for actions, thoughts, student interactions, the elements of project based learning, and critical thinking elements of thought. Notes included observations of group discussions, students working, conversations with groups,
interruptions, difficulties, and daily activities. These notes helped me make sense of what was happening in the classroom learning environment after the learning was completed. The reflective practice is part of action research (Mertler, 2017). Figure 4.8 shows the recurrent concepts from the analysis of my researcher notes and observations.

Table 4.8 *Codes from research notes.*

<table>
<thead>
<tr>
<th>Codes from Research Notes</th>
<th>Number of Codes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assessment</td>
<td>9</td>
</tr>
<tr>
<td>Categories/Categorizing</td>
<td>34</td>
</tr>
<tr>
<td>Purpose</td>
<td>2</td>
</tr>
<tr>
<td>Questioning/Questions Guide Research</td>
<td>24</td>
</tr>
<tr>
<td>Reflection</td>
<td>10</td>
</tr>
<tr>
<td>Planning</td>
<td>29</td>
</tr>
<tr>
<td>Difficulties</td>
<td>24</td>
</tr>
<tr>
<td>Group Dynamics</td>
<td>30</td>
</tr>
<tr>
<td>Motivation/Student Interest</td>
<td>20</td>
</tr>
<tr>
<td>Problem Solving</td>
<td>20</td>
</tr>
<tr>
<td>Researching</td>
<td>6</td>
</tr>
<tr>
<td>Collaborating</td>
<td>44</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>315</strong></td>
</tr>
</tbody>
</table>

Through the process of peer debriefing with my dissertation chair, two ideas emerged regarding the data. The first was to make the connection between the process codes, project-based learning, and critical thinking. To show how these are all connected and part of the project-based learning I moved the concept of reflection to the theme of growing critical thinking because it is one-way students think critically within the project-based learning environment. The other idea discussed was the idea of motivation connected to students having a purpose for learning by reaching an authentic audience.
and how that guided them through their research, planning, collaborating, creating, and presenting of their artifact.

Member checking occurred through a meeting with half of the students who participated in the project-based learning innovation. The project was completed during the Spring of the previous school year, due to scheduling, student relocation, and other issues outside of my control, only 13 students were able to participate in the peer debrief session. I presented students with the themes that emerged and discussed what I had learned about their critical thinking, motivation to learn science, and problem-solving skills. They commented on the process of learning and how it was motivating to work on a topic they had chosen, with people who were working toward the same goal as them and knowing they would have to share their learning motivated them to do a good job. They liked the active learning environment because they felt in charge of their learning.

**Themes**

Themes emerged as I looked at the data through the lens of critical thinking, project-based learning, problem solving, and motivation to learn science. The following themes evolved from the data: 1) Growing critical thinking skills through project-based learning, 2) co-creating artifacts, and 3) reaching an authentic audience.

**Growing Critical Thinking Skills Through Project-Based Learning**

Critical thinking is an important part of learning. Project-based learning strengthens critical thinking skills through questioning, developing conceptual understanding and processing information (Paul & Elder, 2012). In this study, critical thinking is defined as analyzing information by asking questions, reflecting, and making sense of information based on the context. An important aspect of growing critical
thinkers is learning how to think rather than what to think; students need to know how to think for themselves (LaPoint-O’Brien, 2013). Through student reflections and teacher observations four categories emerged to describe: a) questioning b) gaining conceptual understanding c) applying and accessing information and d) reflecting.

**Questioning.** In this study questioning means students generating questions to determine what type of information they want to find about the topic of native state animals. Questioning is related to critical thinking because students have to use analysis to determine if their question is connected to the topic at hand and also if their question will help them to find appropriate information (LaPoint-O’Brien, 2013; Paul & Elder, 2008b). In this process students also have to take in information presented by their peers and synthesize their thinking with the thoughts of others to create new questions or revise the questions they had previously written. Questioning in this study involved a combination of asking questions as part of the brainstorming of ideas, refining questions, and placing questions into categories to clarify the concept they belong to. As part of the questioning process students participated in a brainstorming session where they freely thought about what was related to the topic of native animals. As students thought of questions, it sparked a discussion and led to other inquiries by students. Questioning, brainstorming, and categorizing became a cyclical process where students thought of new ideas, asked more questions, and then put those questions into categories that showed what concept they represented. See Figure 4.9.
An example of this process is evidenced in my researcher notes where students clarified what a question was addressing about the animal and how another question could be the same type of question. For example, one student asked, “What do alligators eat?” and another student said, “We could also ask what eats an alligator?” The conversation continued with me asking students how we could reword the question to include both of these questions. This part of the process led to the creation of categories. Categories refers to the broader concepts that included the ideas covered by the questions.

Some questions were straightforward and could easily be answered with a yes or no answer. The following are examples of this type of questions: Brody asked, “Do foxes live in [state]?” Alexa asked, “Are most animals endangered?” Madie asked, “Do some birds go faster than other animals?” When students asked this type of question, I encouraged them to think about how to change the question into one that could be answered with an extended response. The evaluation of questions is connected back to
critical thinking because students had to consider what concepts or ideas the question was connected to and determine if we could group it with other questions.

As part of the discussion and questioning process, we talked about different types of questions and how some require us to simply perform a Google search, and other questions require more analysis of information. When students wrote the second round of their questions, they had a good idea of what types of questions would lead them to learn more in-depth information about their animal. The action of evaluating the existing question is part of metacognition because it engages students in the analysis of their previous thinking (Elder & Paul, 2013; LaPoint-O’Brien, 2013; Paul & Elder, 2008b). This evaluation and revision of previous thinking and the thoughts of others is part of critical thinking. To further explore the cyclical nature of questioning a closer examination is needed for (a) brainstorming and (b) categorizing.

**Brainstorming.** Brainstorming is defined as throwing out many ideas to determine what ideas were the best for this learning experience. In this study, brainstorming is specifically relating to the process students went through as they gathered ideas and thoughts related to native state animals. This is related to critical thinking because students are practicing metacognition and examining the thinking of their peers as they evaluate what is being discussed (Tuckman & Jensen, 1965). Students have to talk about the topic at hand, as well as, think about the ideas they and their peers have generated. As students began to question, they came up with more ideas about what it would mean to study an animal that specifically lived in our state. An example of this was centered around the concept of endangered animals. One student asked, “What does it mean to be endangered?” Another student referred to one of the videos for an example,
"The video said they are limited in numbers." This conversation started us on a more in-depth conversation about endangered animals and why they may be endangered. After hearing about habitat loss connected with some of the endangered animals’ students were curious about how the habitat loss is happening. This curiosity led to adding questions related to endangered status of the animals. Another student reflected on the questions and brainstorming as examples of how this process helped them think of topics for researching their animal: “For example, what does it eat, where does it live, where does it go when bad weather hits, and does the [state] Panther know when bad weather is coming?” The open discussion and brainstorming of a variety of topics gave students new ideas for questions they could ask about their animal which then guided how they proceeded in their learning process.

**Categorizing.** In this study categorizing is defined as putting ideas and questions generated during brainstorming into a category to better understand how the information is related. Categorizing is relevant to the theme of questioning because students used the categorization of questions to help organize the information, they found during the research process. At one point we during the brainstorming of questions we began to realize many students had similar types of questions. One student had a question about what an animal eats, and another student had a question about what eats the animal. During the discussion, students realized there was a lot of information, and to better keep track of the information, they should begin to create categories for the questions to make it easier to track. This happened quite naturally as students began to see that questions like “What does the alligator eat?” and “What does the Key Deer eat?” were the same question for different animals. As we discussed that they were similar, I asked the
students how we could ask a question that would apply to all of the animals being studied. As a group they decided on “What does the animal eat and what eats the animal?” We began to group the questions in this manner which led us to create categories that encompassed the question groups. Through further discussion, we determined that this is an example of a food chain, and therefore, we should have a category for food chain, so they could make sure to include information about what predators and prey an animal has. Through this discussion the vocabulary words predator and prey were introduced to students who did not already understand the terms. We narrowed the grouping of questions down to six categories: food chain, life cycle, habitats, adaptations, endangered, and other. We created a poster with the categories listed for students to be able to place their Post-it Notes in the correct category. While we discussed the questions, we began to put them into categories. See Figure 4.10.
After placing the questions in categories, we continued our discussion of what questions were the most important or that could be applied to all of the animals we were studying. This analysis of the questions is another example of how students used critical thinking. We had two rounds of questioning which allowed students to have time to reflect on questions already included and what more they want to find out about their animal. See figure 4.11.

Figure 4.11 Poster with categories and important questions for all animals
Responses to the reflection prompts showed students were positive about the questioning process. Students found this process helpful in how they carried out their research because it guided them in what they researched and how they ultimately presented the information.

Sarah: We all asked a lot of good questions. I used the categories to help me find information about my animal by seeing what categories we had, those categories where diet, food chain, endangered, life cycle, habitat, and adaptations.

Tavon: I used the categories to know what to look for, such as diet, habitat, prey, behavior, adaptations and appearance of my animal.

Will: The categories help me find info because I know what to look for, for my animal.

Having the categories as a guide allowed students a starting point but it did not limit their thinking, they were open to find additional information that may add to their knowledge of their animal.

Categorizing as part of the questioning process showed students how concepts and questions dealt with the same ideas and how they were related. One benefit for students was how the categorization guided their research and helped them organize the information they found. They used the categories to help them gather information, plan their educational presentation, and ultimately create their PowerPoint slideshow. Understanding how the questions were categorized gave students a starting place for the analysis of information. The critical thinking involved in deciding which questions fell
into a certain category showed the development of the important concepts within the overall learning in the project.

**Gaining conceptual understanding.** Conceptual understanding refers to a better knowledge of the concepts involved in the learning experience. Concepts refers to the main concepts that were determined important through our questioning activity. Prioritizing ideas related to the study of a given topic and deciding which information or questions are related to a given category or concept is evidence of critical thinking (Zandvakili, Washington, Gordon, & Wells, 2018). Categories and concepts are related in this study and go hand in hand in helping students gain a deeper knowledge of the ideas related to their animal, how it lives, and how it survives in its environment. Students in this digital age have access to an overwhelming amount of information; it is an important skill to be able to analyze the information and make sense of it (The Partnership For 21st Century Skills, 2009). The categories helped students understand the concepts within the project that they were learning about. These concepts included food chains, habitats, and adaptations. Having a better understanding of the concepts essential to the project helped students focus on that information for their project. For example, the following is an illustration of the process of building their conceptual understanding:

Ryan: In the habitat category, we were looking for other important facts like where they lived and what kind of water they lived in.

Emma: For example, when I looked at [a] food chain and saw the question, “Who were the predators?” I looked for that information.

Jacob: We knew we needed to find information about its food chain, habitat, life cycle, adaptations, and other facts.
Students are consumers of information in many different formats, concepts, and situations. When students were confronted with new information, they analyzed the information by relating the new facts to what they already knew. The conceptual understanding grew as students dug deeper into the ideas with which they were presented because they categorized the information in a way that made sense to the learning of their animals. The process of growing a conceptual understanding relates directly back to Paul and Elder’s (2012) elements of thought related to concepts which states, “All reasoning is expressed through and shaped by concepts and ideas.” Combining the existing schema of students with new knowledge related to their animal and the related concepts created the opportunity for students to think critically by evaluating, discussing, and prioritizing information which added to their conceptual understanding.

**Accessing and applying information.** In this study accessing and applying information is defined as the action students take when gathering information and then using that information to demonstrate their learning. Students needed information to learn about their animals, their habitats, and adaptations in order to become an expert and convey what they learned to an audience. This idea of accessing information is similar to the idea of concepts because students used the categories to determine what information would be useful in their learning. Two distinct ideas emerged in connection to information: a) gathering information and b) using information. During the first stages of the learning process students did more gathering of information and then used the information to inform how they carried out the completion of their artifacts. They also found themselves gathering additional information throughout the process as they needed new information. Critical thinking is a part of evaluating information that should be
included in a body of knowledge. Students determined through evaluation of available resources which pieces of information fit with what they wanted to know about their animal.

**Gathering information.** During the initial stages of our learning, students gathered information that aligned with the concepts created during our analysis of student-created questions. Gathering information happened when students did their initial research using the links I provided. They organized their information by the categories decided on in class, using the questions in each category as a guide. In their critical thinking prompt responses, many students referred to the categories guiding their process for gathering information:

- **Tavon:** I used the categories to know what to look for, such as diet, habitat, prey, behavior, adaptations and appearance of my animal.
- **Ryan:** In habitat we were looking for other important facts like where they lived and what kind of waters they lived in.
- **Zeph:** I used categories to help find information about my animal by thinking about how it lives and how it eats and survives.
- **Addy:** I used the categories to help me find out what information I needed to find out so I can put it in the project. For example, what is in the bobcat habitat & where do they live in [state]?

Using the categories to guide the research during the initial process of finding information and learning about their animal gave students an organizational factor to what they were learning. When they got together with their group and discussed what they had already found, they were able to sort through the existing facts collected and
determine what more they needed to know to proceed to the next part of the project.

Thinking about what was missing from their body of knowledge showed critical thinking because they had to analyze and discuss what more would be helpful in allowing them to understand their animal.

**Using information.** Using information occurred during every part of the project-based learning process. Students used the information they had gathered to decide, plan, and create elements to include in their habitat. They used these details to plan and create their educational presentation. When students came to a roadblock in their process, I encouraged them to see if they could find the information in the research they had already gathered or collect new information. Within their groups, students used the information they had assembled to have discussions about their animal, habitat model, educational presentation, and, after preparation, to present what they had learned and created to their audience. Four examples of this type of engagement in discussion using information comes from critical thinking responses:

**Brett:** Our group used information from the website to decide what to put in the habitat. It said that they live in dense wetlands and forests. They appear in the south of [state] and their predator is the [state] Alligator. We talked together about where it lives, near the water.

**Brody:** We went back to our PowerPoint and went to the habitat section and used the information we found to figure out what we needed in our habitat.
Nisha: So first we looked at our information we wrote down and so for example, we saw that one of their habitats is a forest so then we knew that in a forest there are trees and dirt and grass maybe.

Jacob: We all worked together to use the information from our animal and habitat that we learned on the websites to get a picture of what a habitat looks like so we could make a plan.

All of these students reported using the information from the initial stages of research in combination with the information their teammates found to inform their work in the project-based learning process. The discussion and evaluation of information shows students engaged in the critical thinking process. Having an open discussion and sharing of ideas allows students time to discuss, question, evaluate, connect to prior learning, and come to a consensus about what information to use and how to use the information. The process students went through to apply the information they learned aligns with Paul and Elder’s (2012) element of thought, Information, which states that “All reasoning is based on data, information, and evidence.” Students used information in all aspects of the project-based learning process, using critical thinking and analysis to determine how to best use the information.

Reflecting. Reflecting is defined as looking back on part of a process, one’s own work, or the ideas being shared to decide and evaluate the level of progress or success (Ladewski et al., 1994; Smith, 2016). Reflection happened throughout the project-based learning process. Some reflection happened naturally, and some reflection was built in through the use of student reflection prompts, which were placed throughout the stages of the learning. Reflecting involves critical thinking as students work through the learning
process, they must engage in a process of evaluation of what they have done and what still needs to be done (Tawfik et al., 2016). Through the analysis of student reflection prompts and teacher observations two subcategories emerged: (a) reflecting on learning and (b) reflecting on the work of others.

**Reflecting on learning.** Reflecting on what has been learned and identifying what information still needs to be found is a critical thinking skill (Grant & Branch, 2005; Paul & Elder, 2012). Students need guidance to develop this critical thinking skill, and they will develop a deeper level of understanding if given the opportunity to think about their learning process (Grant, 2011). Students can analyze what is missing from the body of knowledge to determine if they need more information to complete their task. An example of student reflection comes from the manatee group reflecting on a piece of missing information. Ryan stated, “We did not know if manatees lived in saltwater or freshwater, so we looked up more stuff about the manatee and we saw that they live in freshwater.” He reflected on the group needing more information about the type of water the manatee lived in and how they went back to look up more information about the topic to add to their project. The [state] panther group had a similar situation when deciding what to put in their habitat model. Tavon stated, “We went back and did some research and figured out what to put in there.” The group needed to reflect together about what more they needed to learn in order to create a model of their habitat. Another reflection opportunity was noted from my observations during the research phase when students met with their group to share the information they had already found and determined what information was still needed to begin working on their artifact. Students then made a plan for how they would find the remaining information.
Reflection of one’s own work is a hard but necessary part of learning and helps to grow critical thinkers (Grant & Branch, 2005). Students have a hard time evaluating their own work, they have a hard time separating what they intended for their work and what they have actually put down on the page.

**Reflecting on the work of others.** Reflecting on the work of other groups happened during a gallery walk in the middle stage of creation. Students walked around to observe the work of their peers and discuss the work they had done to create different elements of their habitat models. These discussions were noted in my observation. They shared techniques for making different parts of their habitat which also gave some groups an idea that helped them add more to their habitat models. For example, one group was trying to make a tree for their habitat out of popsicle sticks and pom-pom balls, but it didn’t work, they shared how they instead used some felt and wrapped it around a painted popsicle stick to create the tree. The investigation of the work of other groups led students to go back to their habitat and make changes.

During this time, they discussed their new knowledge of their own animal in relation to the other animals in class. One statement that was noted more than once was, “The American alligator is my animal’s predator.” This made for some conversation about how the food chain works and which animals are included in the food chain of the American alligator. These conversations added to presentations later in the project when students were sharing with their audience. Students were heard telling the visitors to their habitat: “Make sure you visit the American Alligator exhibit. They are our predator.” The students became interested in the work of other groups and were excited to see each other’s work by the end of the learning process. They had the opportunity to walk around
and visit each other’s exhibit after all presentations had been finished. The process of reflecting on the work of other students helped students share their knowledge with each other and ultimately improve the outcome of their artifacts and overall learning.

Reflection as part of the project-based learning process was important for student learning and success. The act of thinking about their own work and the work of other students gave students insight into the success of their own project. It also allowed them to learn from their peers. Within an extended learning experience such as project-based learning, it helps students keep their focus strong on the end result when they can stop and think about what they are doing and why they are doing it. This evaluative reflection process has added to the growth of critical thinking skills. Reflection is a powerful tool when used in conjunction with learning. Students reflecting on the process of their learning helped them to understand what next steps to take in their learning and artifacts.

Co-Creating Artifacts

Creating artifacts is an important part of the PBL experience. In this study, co-creating artifacts is defined as the process of creating a product in collaboration with one or more other students. Part of the process of project-based learning is students using their new knowledge to create an artifact that demonstrates what they have learned (HQPBL, 2017). An important part of the creation of artifacts in this study is the collaboration among students. Through student reflections and teacher observations, three categories emerged: a) collaboration, b) problem solving, and c) negotiating and compromising.

Collaboration. Collaboration is defined as working together with others to produce or create something (Thomas, 2000; Krajcik, 2000). According to The
Partnership for 21st Century Learning (2010), collaboration skills are important for future ready students who are able to work with a variety of people in many different contexts. Collaboration is an important aspect of the process of project-based learning (Tamim & Grant, 2013) because students are working on a shared learning activity where they have to come together with ideas and skills to learn and demonstrate their learning (Krajcik, 2000). In this project-based learning experience, students collaborated by sharing information they found when researching, creating a model of their animal’s habitat, creating a digital educational presentation, and presenting their artifacts and information to an audience. Collaboration can take many different forms. For the purpose of this study, I present two different types of collaboration carried out: a) analog collaboration and b) digital collaboration.

**Analog collaboration.** Analog collaboration would be considered any collaboration that is not done through a digital format. An example of analog collaboration from this study is students working together to create a physical model of their animals’ habitat. Many times, students, in groups of two to four, began their collaboration with each other in face to face meetings where all students could speak directly to each other about their ideas. An example of this comes from my researcher notes: “Student desks were moved so that students are sitting with their animal project group.” The movement into animal groups allowed students instant access to their group mates, which allowed them to share ideas quickly and easily. Another observation from my researcher notes shows students checking in and collaborating on their next steps: “Students had a conversation about what they have already found out about their animal and what information from our question session for which they still needed information.
The groups then made a plan for how to find the rest of the information needed.” This checking in provided students time to reflect on their progress and plan for any information they still needed to gather. Student reflections showed evidence of this analog collaboration too. For example, three students expressed the following:

Abby: We looked in our journals and discussed what we should have in our habitat.

Addy: All the people in the group discussed what to put in the project and what was the most important thing to put in the project.

Ava: We all made a list about what the red fox needs and then we got together and talked about everything we wrote down. Then we drew a picture of what it was going to look like in our pizza box then we started to paint the box and make it look like what we drew.

Working on a project within a group gives students the opportunity to collaborate with their peers, share their thoughts, and learn from each other (Marx et al., 1997). Collaboration is a skill that students need to have in order to succeed in our 21st Century workplace (P21). Practicing the skill of collaboration throughout the stages of project-based learning gave students new skills to take into future learning opportunities.

**Digital collaboration.** Digital collaboration involved students using digital tools to complete work in an online environment. An example of digital collaboration from this study is students sharing a PowerPoint presentation where they all type or work on different slides to create their educational presentation. One observation that shows this sharing of skills happened on day eight of project work: “Groups were helping each other
when they got ‘stuck’ on how to add slides, add pictures, or change the layout or design.”

Another observation that shows this sharing of knowledge between students was noted on day eleven: “Some groups have more technological abilities and they found transitions and changing font easy. They were then showing other groups how to do these things.”

Students became an expert sought out by their peers. Students commented about using a Microsoft Word document to collaborate in order to organize the information to then put it into their PowerPoint presentation.

Sarah: We take that information and we write it down on the planning page on the computer and we take that information from the planning page and put it into a slideshow.

Addy: We put the things in sections in our Word document, so we did the same with our power point.

Ava: We planned it in word, organized by slide 1, slide 2 until we had enough slides. For information we typed the information down, then when we typed everything on each slide, then added pictures and designed the slides.

Giving students tools for collaboration and training in how best to use these tools builds student confidence in trying new skills and becoming the teacher to other students.

Collaboration within groups through digital avenues allows students to work together toward a shared product. This digital collaboration gives the teacher a window into the work students are doing, the teacher can see what individual students have contributed and the progress the group is making in the project. Co-creating artifacts involves many different parts to come together in the right way to have the product reflect the learning.
Digital tools can be useful to students as they keep track of information and create content.

**Problem solving.** Problem solving in this study is defined as overcoming issues that arise throughout the process of learning and creating. As students moved from researching information independently, to collaborating, to putting the information together, to creating their habitat and educational presentation, they had to work through a variety of issues (Paul & Elder, 2012). Each student had already begun to create his own idea of what each part of the process or artifact would look like. Having a plan for discussions or conducting an example discussion can help students manage the project elements (Herro et al., 2017). When student teams came together, they had to talk through the process and make decisions. An example of each student bringing their own ideas is shown in the critical thinking response questions:

Sarah: One person didn't want to do life cycle because there was only one fact in that section. So, we added more information to the life cycle section on our PowerPoint and that solved the problem to our disagreement.

Isaac: We did not agree on how to make the trees because I thought about putting green pom poms on brown Popsicle sticks. Then we came up with using green fabric and we solved the problem by looking at which one looked the best and worked much better. So we went with the fabric because it looked best.

To work collaboratively and solve problems effectively and efficiently, students must consider the ideas of their peers. The synthesis of one's own ideas with the ideas of others
is an area of critical thinking where students need instruction and guidance (Paul & Elder, 2012). Two subcategories related to problem solving emerged: a) problem solving through consulting resources and b) additional approaches to problem solving.

**Problem solving through consulting resources.** Problem solving happens throughout the process of creating in project-based learning (Jonassen, 1997; Marx et al., 1997). Students solved problems in each stage of learning within the project. With collaboration and multiple minds working towards a shared product and process, there are problems involving differences of opinion, ideas, how a task should be completed, and differing point of view of how something should look. One of the ways students solved their problems was to consult their research or the resources again to see if they could find answers to their questions or problems. Four examples of student problem solving are depicted in student reflections about creating their artifacts:

- **Ryan:** We had one problem, it was that we did not know if manatee[s] lived in saltwater or freshwater so we looked up more stuff about the manatee and we saw that they live in freshwater.

- **Isaac:** The problem was that we did not know how to make the Alligator look like an alligator and it was a problem because we needed a good-looking alligator. So, we used a reference picture to help us make it look as good as it did.

- **Zeph:** When we were doing our power point we disagreed on a couple pictures for example when we were doing the fights category we disagreed on a picture I said I wanted, he didn't want to do the one I wanted to do because there was some blood on one of the deer
antlers, we made a solution by checking out some other pictures of key deer fighting other key deer and then we found a picture of key deer fighting key deer and decided we would do it.

Nick: One time we did not agree on what picture to have on the manatee project picture and we all got together and searched up pictures and then we agreed on what to do we all decided on a picture. We all talked about one picture to represent the manatee. Like what it looks like if everyone in the world thought of a manatee that would be the picture.

When faced with a problem or disagreement with their group mates, students consulted the resources available to them. The additional information helped them to sort through the problem and create a solution. Solving problems can be as easy as a discussion to determine which idea to use or it may require searching for more information to settle a dispute. Sometimes there is a level of compromise or negotiation that happens where one student gives up something for the benefit of the group's success. Having the opportunity to use collaboration, resources, and negotiation to solve problems within the context of the project is part of the critical thinking skills necessary for problem solving. Students can use collaboration to explore ideas, decide which concepts are the best in the context, and determine what is important for the task at hand (Marx et al., 1997; Thomas, 2000).

In the project-based learning classroom, students have to learn to collaborate by discussing ideas, thinking through how best to use information, and what is necessary to accomplish the goal of co-creating their artifact to successfully share their learning.
**Additional approaches to problem solving.** Some student groups in the study had more issues than other groups. Some groups worked more easily with each other because they were open to the thoughts of their teammates. Groups approached tasks in different ways which may have led to more strife or more productivity. Some groups avoided problems or gave into their teammates easily to avoid lost time, arguing, or simply because they did not have as strong of an opinion as their partners. Other groups asked for help from me, the teacher, in their problem-solving attempts. Sometimes the problem came from inside the students themselves. Examples of different approaches to problem solving are evidenced in the following student reflections:

Christian: I drew a really good picture once. But I couldn't draw it again. But it looked better than my teammates drawings. I was afraid of embarrassing myself. So, my teammates said, "it looks fine!" So, then I was not afraid anymore.

Abby: Christian wanted to put rocks around the hole I made but I did not want the rocks around the hole because I don't think that there would be rocks around a hole in the wild. We were arguing and then I just said fine and we put the rocks around the hole.

Emma: Once, during making the flamingo PowerPoint, my teammates kept getting off task. This was a problem because when they did this, they weren't working so I tried scooting back in my chair and it worked! So, every time they got off task I scooted back in my chair.
Landon: When we were putting on our finishing touches on our habitat my group all thought that we should put lily pads in our pond. So, I said we shouldn't put lily pads in our pond. So I asked Mrs. Lawson if we should and she asked if the resources said anything about lily pads.

These examples illustrate the process some students go through as they try to address problems they encounter. Some students have experience with figuring things out and making things work with little help from the adults around. They are analyzing situations not realizing they are using critical thinking and problem-solving skills (Grant, 2011). Some students have been helped through many situations by asking for help when things do not make sense, or they cannot solve a problem. Students do not often spend time thinking about other people while problem solving; they want to have things the way they want them. Student problem solving skills are in their development phase, to be successful with this development students must be taught critical thinking skills.

**Negotiating and compromising.** One way students solve their problems is through negotiation and compromise. Negotiating and compromising is defined as presenting and discussing the wants of each person and making a mutual decision that is acceptable to all people in the group (Krajcik, Blumenfeld, Marx, & Soloway, 2000; Thomas, 2000). To co-create their artifacts student teams had to bring ideas together that required negotiating and compromising. In the project-based learning environment, students take responsibility for their learning (Cetin-Dindar, 2016). Student responsibility leads students to have higher stakes in their learning outcomes, in this case their artifacts. The higher the stakes, the more students must negotiate and compromise to reconcile
what they think is most important to the project (Blumenfeld et al., 1991; Guay & Bureau, 2018). Examples of negotiation and compromise come from student reflection prompt responses:

Will: When me and Zeph were doing our PowerPoint we could not choose if we wanted to do the Slide transition or Fade transition so instead of doing one transition, we did all different transition on all different slides so we did not have to fight or waste time just trying to choose a transition for our PowerPoint. so we fixed that problem and we were good.

Nick: One time we did not agree on what picture to have on the manatee project picture and we all got together and searched up pictures and then we agreed on what to do we all decided on a picture. We all talked about one picture to represent the manatee. Like what it looks like if everyone in the world thought of a manatee that would be the picture.

The thoughtfulness these students put into choosing the exact right picture or creating a visually appealing presentation shows how invested they were in creating their artifact. Negotiating and compromising with their teammates was essential to creating what they thought would be the right product to show their learning. When students collaborate, they work together by providing each other with information, insight, and creativity they are more likely to succeed (Tamim & Grant, 2013; Yager, Johnson, Johnson, & Snider, 1986). Co-creating artifacts has a level of collaboration that requires students to think
about the opinions and desires of other students to create a product that conveys the knowledge they gained in the learning experience.

**Reaching an Authentic Audience**

Having an authentic audience to share their learning gives students a sense of importance in their work. In this study having an authentic audience is defined as an audience from outside the classroom. Students are able to present their learning to an audience that benefits from their knowledge (Defauw, 2014). In previous research it was found that understanding the potential audience helped students take ownership of their project (Chen & Brown, 2012). The presentation of learning to others through artifacts gave students an authentic audience with which to share their learning and created a sense of excitement and ownership in their work. Through student reflections and teacher observation two categories emerged: a) purpose for learning and b) student reactions to sharing their learning

**Purpose for learning.** Understanding the audience helped students to have a sense of purpose for their research and work throughout the learning experience. Student motivation is closely tied to having a purpose for learning (Chen & Brown, 2012; Defauw, 2014). Students understood early in the project the idea of who they would be sharing their learning with, and this directed their learning preparing them to be experts in their animal. Focusing on the potential questions asked by their audience, students began to build a knowledge of their animal and its habitat. For example, five students spoke directly about this purpose:

Ava: I needed facts in this category and if someone asked me a question that was on there, I would know the answer.
Nick: We made different slides on different categories to inform the people about the different things about manatees.

Alexa: When people ask these questions, they have a slight chance of getting an answer.

Caleb: The questions in class helped because I knew what to look for so we could answer all the questions people asked.

Nisha: I knew that these were the facts that I was probably going to get asked. Like, for example, someone could ask me about what my animal eats or where they live. So, then I knew that if I answered those questions, then I would be ready when people ask me questions about my animal.

Nisha: The categories helped me find information about my animal because they had a bunch of topics and I thought to myself that people are going to ask me about those topics. For example, diet, food chain, adaptations, and life cycle were some of the things that were on the topic, so I got facts about all of those topics and put them in separate topic columns and then was ready to show people about the facts.

Nisha: I looked at how my animal's life is so different, so then I knew that some people probably do not know this, so I'm presenting it with my group so people can know new and interesting facts.

Students took pride in what they were creating, often returning to the research links to add to their body of knowledge. If a group came upon an idea or topic, they were not sure
about they would discuss it, look for more information, or ask for help. The purpose for learning became motivation to have a successful project. Knowing the intended audience gave them direction on how to present the information and influenced their communication of the information. This finding is connected to the research Chen & Brown (2012) conducted where students took ownership of their learning by focusing on their audience to complete the task of learning. Their students developed new skills necessary to complete the tasks successfully. My students sense of purpose was a driving factor in staying focused to manage the completion of their project.

**Student reactions to sharing their learning.** The feeling of being an expert on a topic gave students the confidence to fearlessly share their learning. For example, when presenting to administration and other teachers my students made eye contact, spoke directly to the adult, answered questions, and were animated in sharing their learning. During the final presentation of artifacts to the kindergarten class, the students were visibly excited. One of the behaviors observed, getting down on the level of the kindergarten students, showed a desire to effectively communicate their information. Another observation I noted was the questioning of the kindergarten students to determine if they were understanding the new information.

Students were not only proud of their own work, but they wanted the opportunity to share in the learning of their classmates by visiting their animal display. This show of caring and community within the classroom was seen throughout the project and carried over to the sharing of knowledge. They felt as though they were experts with valuable information to share and this gave them confidence in sharing their learning (Chen & Brown, 2012). We took some time at the end of the presentation to have students share
how their final project turned out. Although we conducted gallery walks throughout the process to gain knowledge and offer suggestions, this sharing time was different. The students were educating each other and finding connections between their own animal and the other animals studied in the project.

Chapter Summary

For this study, quantitative and qualitative data were collected. Quantitative sources included 1) Science Content Assessment – Animal Adaptations and Habitats, 2) Motivation to Learn Science Survey, and 3) Project Assessment Rubric. Qualitative data included student critical thinking prompts, researcher notes and observations, and teacher rubric comments. Three themes emerged from the data: 1) growing critical thinking skills in project-based learning, 2) co-creating artifacts, and 3) reaching an authentic audience. The analysis of the data and creation of themes helped me understand the outcomes of the study.
CHAPTER 5

DISCUSSIONS, IMPLICATIONS, AND LIMITATIONS

This chapter positions the findings within the existing literature on the impact of technology integrated project-based learning on critical thinking, science content knowledge, and motivation to learn science content. The purpose of this study was to evaluate the implementation of technology integrated project-based learning in fourth grade students at Firebird Academy in a suburban area of the Southeastern United States. This chapter will present (a) a discussion, (b) implications, and (c) limitations.

Discussion

It is important to situate the findings of this research within the larger context of research. The literature on critical thinking, science content knowledge, and motivation to learn science help position this study in the larger body of knowledge. To answer the research questions, the data were combined and considered through a lens of project-based learning, technology integration, and motivation to learn in the science classroom. The discussion is organized by three research questions.

Research Question 1: How does the implementation of technology integrated project-based learning affect the critical thinking skills of fourth grade students?

Critical thinking skills allow students to connect with information and concepts in deeper, more meaningful ways (LaPoint, 2013). In this study critical thinking involved questioning, gathering and assessing information, interpreting information, thinking openly to assess needs, and communicating effectively to solve problems. Students
approached each aspect with the mindset of improving their work through evaluating and analyzing ideas, progress, and the work at hand. Evaluation and analysis are connected to the work of critical thinkers (Feely, 1970; Paul & Elder, 2012). Creating a culture of critical thinking requires the opportunity to ask meaningful questions, think critically about ideas, and solve problems that are relevant to students.

**Raising Questions.** In the beginning stages of our project-based learning experience students were shown two videos to introduce them to animals that are native to [state]. Students had many questions about the animals they saw and began to think about how the animals lived in their environment. The act of questioning helps students make sense of what they are learning (LaPoint-O’Brian, 2013, Paul & Elder, 2002). In this phase of questioning, it was important for students to get their questions down on paper. Students did a free write of questions they were thinking about. Some students were reluctant to write questions stating, “I don’t know what to write.” Other students went right to work and wrote multiple questions. Students who were more interested and genuinely curious about the animals and the impending project worked furiously to get their questions out. Students who were not interested wrote no questions or one question that required a limited answer. LaPoint-O’Brian (2013) found similar results when students were asked to write questions related to their minute papers. LaPoint-O’Brian found when students were bored with the topic, they used less critical thinking skills, writing simplistic questions.

We then had a discussion about what makes a good question for our purpose. Students used their first round of questions for evaluation. We looked at questions like, “Do alligators eat snakes?” to determine if it required an extended answer or a limited
answer. After discussing how this question could be answered with a yes/no response, we discussed how the idea of what an animal eats to survive is a good concept to think about when investigating an animal. To explain why students, ask these types of questions, Krajcik (2000) posits, “One possibility is that students do not have enough experience with inquiry to fashion meaningful questions” (p. 16).

We also looked at questions like “How many animals live in [our state]?” and “How many foxes live in [our state]?” as questions that would be impossible. We discussed how you could never know exactly how many of an animal live in the state because they move around. We talked about how we could estimate based on how many are in one part of the state or region, but we could not get an exact answer. We evaluated the questions for their connection to our content then revised them to reflect a question that could guide thinking through the project. Evaluation of the previous set of questions gave students the opportunity to think critically by reflecting on the quality of the question. When a student shared their thinking the evaluation of that question was evident in the class through the comments or related questions being shared. For example, one student revised his question from, “How big is an alligator?” to “How large is an alligator during different parts of its life?” showing growth in realizing the animal would grow and change throughout its life. Another example is shown through the transformation of “Why do humans impact an animals’ habitat?” to “How do humans impact the environment and habitat of [native state] animals?” showing a movement to a question that can be answered from the examination of information provided. Questions drive thinking and as such students need to engage in questioning activities to support the development of critical thinking skills (Elder & Paul, 1998, Rashid & Qaisar, 2016). The
development of questions related to a specific native state animal or state animals in
general led students to think critically about the information they would need for their
process of learning.

**Gathering and assessing information.** Researching was the next step in the
project-based learning process connected to critical thinking. One connection to critical
thinking is the evaluation of information (Paul & Elder, 2001). When students were
immersed in information related to their animal, they had to use analysis skills to evaluate
whether the information would answer the questions they had or provide valuable
information to add to their project. García-Rodicio (2015) found that active questioning
allowed students to organize their thinking and learning. In this study students used the
questions they wrote to organize the information as they analyzed it, asking themselves if
information fit into one of the categories created during our initial stage of the project.
Students sorted through the information to determine which parts applied to the task at
hand. For example, when creating their habitat model, students used information related
to the animals living environment to add elements to enhance their model and make it
more realistic. For example, one student referred to how they searched for information;
“What is in the bobcat habitat & where do they live in [state]?”

As part of this process of sorting through information, students had to think not
only about the information they gathered but if what they were presenting was accurate.
Paul and Elder (2001) posit the analysis and evaluation of information to solve problems
is part of the critical thinking process. Students were given information through links in
their Microsoft OneNote classroom notebook. They then had to search through the
information to find what elements were relevant to their project. The questions helped
students to decide which information was valuable for their project. An example of this thought process is illustrated in Caleb’s critical thinking prompt response, “The questions in class helped because I knew what to look for so we could answer all the questions people asked.”

**Effective communication.** Problem solving requires students to use critical thinking skills to manage their environment or project in conjunction with those around them (Leader & Middleton, 2004; Ravitz, 2010). The age of students can affect how they problem-solve. Younger students who have not been encouraged to solve their own problems will run to an adult to solve the problem for them. When students are taught skills related to solving problems, they have a variety of strategies to use when they encounter a problem. Communicating with students before the inception of the project can scaffold learning in a way that promotes critical thinking and problem solving. For example, teachers can model how to interact with a small group, showing the importance of listening to team members to ensure everyone has input on the project.

It is also important to explicitly teach the skill of problem solving by analyzing different situations and the ideas of others to determine which route is the best way to solve a problem. Nick illustrated this type of communication in his critical thinking reflection prompt related to a problem his group encountered. Nick stated, “We all talked about one picture to represent the manatee. Like what it looks like if everyone in the world thought of a manatee that would be the picture.” The group not only took into consideration what the members of the group thought, but what would their audience think and how could they best represent it for them.
Working cooperatively in small groups is part of the project-based learning experience. Shared experiences create a level of cooperation and problem solving that helps students become successful in their learning (Tuckman, 1962; Johnson & Johnson, 1986). In this study students had to work through problems during each phase of the project. They came to the problem with different ideas, to get their ideas into the artifact they had to negotiate. Tuckman (1962) found, groups were better at problem solving than individuals working alone. Johnson et al. (2012) found the more opportunity students had for working collaboratively to process information with the use of reflection or processing, the greater their success at learning the topic became. Krajcik et al. (2000) stated, “Effective collaboration requires students to share ideas, take risks, disagree with and listen to others, and generate and reconcile points of view.” When students are working together toward a shared goal, they need instruction on how to communicate within their group to work and solve problems. The scaffolding of these skills helps students build the skill of problem solving and promotes critical thinking (Krajcik et al., 2000).

Another aspect of communication involved feedback from peers and the teacher. While students worked in groups, they received instant feedback from their group members, but they were also given opportunities to view the work of other groups. The production of artifacts in the project-based learning process is a way for students to communicate about ideas and receive feedback which they can then incorporate into revision of their work (Krajcik et al., 2000).

**Research Question 2: How does the implementation of technology integrated project-based learning affect science content knowledge in fourth grade students?**
To answer this question both quantitative and qualitative were integrated. Science content knowledge is measured using two methods; an end of unit content assessment and the analysis of the digital presentation with the use of a rubric. The qualitative data are presented from my notes about student final presentations and include information that was not presented in any other form of assessment.

**Content assessment are reported.** The quantitative data comes from the pre- and postassessment students completed. The assessment evaluated student knowledge of concepts related to animal habitats, food chains, and adaptations. Students showed a significant increase between preassessment ($M = 10.24, SD = 2.57$) and postassessment scores ($M = 12.76, SD = 2.59, p < .001$). Students scored significantly higher on the posttest than the pretest. Item Eight, related to the definition of an adaptation, showed the highest growth from pre- to postassessment (28% v. 80% correct). Item 18, related to the definition of a habitat, was answered correctly by all students on the postassessment. These definitions are major goals of the project and the science standard being studied. Question 11, related to how traits are passed on from parents to children, had the lowest score on both pre- and postassessment.

Students in this study participated in learning together to achieve a common goal. The opportunity for group processing and discussion of ideas leads to higher achievement on academic assessments (Bertucci, Johnson, Johnson, & Conte, 2012; Yager et al., 1986). In their study of cooperative learning groups, Johnson et al. (2012) found that students experienced a higher learning achievement when they experienced group processing. This finding matches student assessment results, students performed higher
on the postassessment after participating with their small group to learn about and share the finding of their research.

**Digital presentations.** Digital presentations were assessed using a project rubric with five topics for evaluation. The rubric had a scale of 3-above expectations, 2-meets expectations, and 1-below expectations. The category related to describing how an animal’s habitat is affected by humans had the highest variation in scores ($SD = 0.77$). This result is interesting because this was a major component of the project and students were very motivated and engaged in the making of their habitat. Also, students were able to explain their animal habitat to visitors easily. Three groups scored 3-above expectation in this category, including information about how humans are impacting the environment of the respective animal. For example, the Key Deer Group included information about how lost habitat, people illegally feeding, and people hitting the Key Deer with their cars all contributed to the reduction in species population. Another example from the first Red Fox Group explained how humans are predators because they hunt the red fox for sport or because of disease or nuisance. Three groups scored 2-meets expectations. The Manatee Group included extensive information in their presentation to visitors of their exhibit about the impact humans have on the endangerment of manatees. They were very enthusiastic in their relating of how humans often hit manatees with their boats, killing or injuring the animals. Two groups scored a 1-below expectations in this category because they did not include information in their digital presentation. However, the American Alligator Group included information about how humans were impacting the habitat during their presentation to visitors of their exhibit. If the information shared had been included in their digital presentation, their score would have increased. Production of
artifacts is one form of assessment in the project-based learning environment. However, an artifact is unable to represent all that has been learned (Grant & Branch, 2005). This constructivist approach to learning allows students to demonstrate their learning and the process of learning in an alternative product (Krajcik et al., 2000). Because students do not have experience with this type of learning they may not understand what information should be included or how to include the information (Marx et al., 1997). Krajcik et al. (2000) posit student interest could may initially lead to information gathering but lack of experience delivering information for the purpose of teaching others leads to minimal elaboration. This outcome was shown with some student groups in the current study.

Final presentation of student learning happened through an exhibit of animal habitat models and digital presentations in the classroom. Three different grade-level groups visited the exhibit throughout the day. My students were also given the opportunity to view their peers’ final product. Informal assessments were conducted through observation during these presentations. Although the presentation was not part of the assessment for this study, it should be noted that student learning was evidenced in their presentation to visitors. For example, the Manatee Group showed a deeper level of understanding when presenting how humans impact the population of manatees by describing and giving examples, such as how humans throw trash like water bottles into the ocean and manatees eat them and can die.

Project-based learning is an avenue to learning science content knowledge (Defauw, 2014; Krajcik & Blumenfeld, 2006; Krajcik et al., 2000). When teachers use scaffolding to introduce not only science content knowledge but the elements of the 21st century learning, there is a greater understanding of the science content. Communication,
collaboration, critical thinking, and problem solving are all part of working in a small group to accomplish a shared goal. Students in the project-based learning environment are in charge of their learning and the teacher is their guide, leading them to the intended knowledge (Krajcik et al., 2000).

**Research Question 3: How does the implementation of technology integrated project-based learning affect the motivation to learn science content in fourth grade students?**

Qualitative and quantitative data were also used to answer this question. The findings showed student motivation to learn science grew through the process of project-based learning impacted by (a) types of motivation for science (b) voice and choice, (c) authentic audience, and (d) deeper connections.

**Types of motivation for science.** To measure student’s motivation to learn science Glynn’s (2011) SMQ-II survey was evaluated and adapted to reduce the total number of questions, making it more accessible to fourth grade students. The survey looked at two types of motivation: intrinsic motivation and grade motivation. Of 26 students, 24 completed both the pre- and postsurvey. Pre- and postsurvey scores for intrinsic motivation ($M=3.70$ v. $M=3.90$) and grade motivation ($M=4.20$ v. 4.20). The data from the motivation to learn science survey did not show significantly higher scores.

Motivation to learn science is present when students know what they are learning is an authentic activity that allows them to be involved in real world problems that may impact their lives outside the classroom (Grant, 2011). The learning becomes the most important part of the process, not the grade. I this study, students were genuinely interested in learning about their animal, not for the promise of a grade but rather for the
success of their project and presentation. For example, Ava stated, “I needed facts in this category and if someone asked me a question that was on there, I would know the answer.” She was referring to her overall success of the project not the grade associated with the artifact or a test that would be administered after the end of the project.

One interesting finding in the survey data was related to grade motivation. Students were interested in doing well in science for the purpose of getting good grades, but they did not want to do well at the detriment of other students. As students completed the survey, they did so at a table sitting near the teacher, giving them the opportunity to ask clarifying questions prior to giving their final answer. Item 10 asked students, “I like to do better than other students on science tests.” This was interpreted by students as a negative because they also wanted their peers to do well on science tests. Students repeatedly asked for clarification on this question stating, “Does that mean I want to do better than them on the test?” or “Does that mean I want them to do bad?” These questions came as a surprise to me because I had not anticipated this view from students.

Voice and choice. Giving students a voice and choice in what they are learning is one element of project-based learning that is motivating to students (M. J. Harris, 2014; Strobel & Barneveld, 2009). This experience showed an increase in motivation to learn science content due to students having a voice and choice in their learning experience. Student choice is one aspect of project-based learning that gives students ownership over their learning and allows them to feel they have an influence over what they are learning and how they are demonstrating their learning (Boss, Larmer, ASCD, & Buck Institute for Education, 2018; Grant & Branch, 2005; Martelli & Watson, 2016; Ravitz & Blazevski, 2014). Through the introduction event and questioning phase I learned
students were interested in additional animals (e.g., key deer and flamingo) and I added them to the list of animals to be studied. Also, there was a large interest in the red fox leading to the creation of two groups studying the same animal.

Another element of the project that came from students was the inclusion of *endangered animals* as a category for our questions. Students were keenly interested in how and why animals were endangered. Student questions guided the creation of categories for the project. Scaffolds were in place to guide students to several category developments but many of the scaffolds were unnecessary because of student interest in the topic.

Students had many choices throughout the learning process. Students chose the animal they were most interested in learning about which gave them ownership of the learning because they were not forced to study something, they were not interested in. They made a connection with the animal and in their group to create a product that was meaningful.

Also, when making their animal habitat they had very few restrictions. Students were required to represent the true habitat and include their animal. They could use any supplies available or bring in supplies to use. Martelli and Watson (2016) found students were more motivated in their learning when they made a personal connection to what they were studying. Students in my class had a similar reaction because they were personally invested in learning about their topic so they could adequately deliver the information to their audience.

**Authentic audience.** As part of setting the stage for the project, students were informed they would be learning and creating artifacts to be shared with an audience of
other students and parents. The concept of reaching an authentic audience gave the students a purpose and direction for their learning. An authentic audience is outside of the regular classroom environment. Defauw (2014) defines an authentic audience as one that has a meaningful purpose beyond school. The purpose of this learning experience included creating artifacts to share with other learners with the intention of teaching the audience about their animal. Grant (2011) examines what influences student work and learning, this is connected to the concept of an authentic audience because students were impacted by the intended audience as they collected and used information. Creating a purpose for learning gave students motivation to increase the level of performance and learning throughout the process. Creating a purpose for learning through reaching an authentic audience leads to student motivation for learning science content knowledge. This finding is similar to Defauw’s (2014) study where students were asked to create a picture book to share science concepts with younger students. Her students demonstrated an understanding of the audience and their needs in the completion of their books with adequate explanation for the younger students.

Having the focus of an authentic audience gave students ownership over their work. Knowing who the audience was gave them direction on how to present the information and influenced their communication of the information (Chen & Brown, 2012). Chen and Brown (2010) found as students worked through their production of an artifact, they used their knowledge of the audience to communicate precisely what they wanted in a way that was understandable to the audience. This study found similar results as students worked through the task of producing their digital educational presentation.
They often stopped to think about what they were communicating and how they were conveying it.

**Deeper connections.** Extended and repeated interaction with the science content made for deeper connections to prior knowledge. The deeper connection helps students to understand information and retain the concepts they have learned (Tawfik et al., 2016). Students had a specific purpose for the knowledge they were gaining; they wanted to know more to fulfill this purpose. For example, one student (Nisha) commented on the purpose for learning, “So then I knew that some people probably do not know this so I'm presenting it with my group so people can know new and interesting facts.” This desire to or purpose for learning helps students make connections between previous knowledge and new content knowledge (Grant, Ross, Wang, & Potter, 2005; Krajcik et al., 2000). As these connections are made and get stronger because of repeated exposure to the content, students deepen their level of understanding. Grant (2005) found a similar result in students’ knowledge evident in their research papers and exhibits.

Project-based learning favors long term retention of information (Harris, 2014; Strobel & Van Barneveld, 2009). One aspect of project-based learning that helps with retention of information is interdisciplinarity, or the connection to multiple content areas (Defauw, 2014; Zawilinski, 2016). Zawilinski (2012) and Defauw (2014) integrated science concepts with literacy concepts, drawing on students’ literacy skills to develop a book to teach younger students about science concepts. Students showed a deep connection to the science concepts at hand but even more impressive was how the literacy skills strengthened through the process. The findings of this study are similar to these studies because my students used their knowledge of informational writing to
develop their digital educational presentations, incorporating text features to enhance the writing.

**Summary.** The structure and autonomy of project-based learning is an internal motivator because students take pride in their work making them want to do good work. Students feel an external motivation as well because they are held accountable in authentic ways. They are responsible for presenting their findings to an audience, they do not want to let their audience down by not knowing enough about the information they are presenting.

**Implications**

This research has implications for me, classroom practitioners, and scholarly practitioners and researchers. Four types of implications are considered: (a) personal implications, (b) implications for technology integration, and (c) implications for project-based learning, and (d) implications for future research.

**Personal Implications**

As a result of this study, I have learned many personal lessons that will help me in planning for my own classroom practice and guiding teachers in the future. These include (a) changed perceptions of teaching and learning, (b) unexpected findings, (c) implementation of project-based learning, and (d) becoming a scholarly practitioner.

**Changed perceptions of teaching and learning.** As teachers we want to be in control of our environment to make sure we know what is happening and that everything that needs to be accomplished actually is. With project-based learning, you are dealing with an active learning environment, where many different tasks need to happen and could all be happening in different ways within the classroom (Grant & Hill, 2006).
Shifting your mind is a part of accepting the different structure of project-based learning and moving toward student agency in the classroom. Students become the drivers of their educational experience and rely on each other to make things come together. As a teacher who is used to being in control of the classroom environment, this change has been a hard but welcomed adjustment. I have had to rethink both what I want my classroom to look like and what it looks and feels like for students to learn and grow in this environment.

Students have a natural desire to learn; they are curious. Students that come to my classroom have also been using technology as long as they have been able to talk. I assume they come to me having the skills to operate different software applications. In reality, these students need direction on how to use technology properly within a classroom setting. As I planned for this learning experience, I had to ask myself what students would need to be taught when considering the technology to integrate within the project. My desire was for students to use technology to gain knowledge, apply knowledge, and share findings with an audience. I found that I needed to demonstrate to some students only once how to do something while others needed repeated directions and opportunity for practice. Student experts (Zawilinski, 2012) also emerged within the classroom and became effective trainers to other students on how to do certain tasks on the computer.

A significant mind shift for teachers is letting go of the belief that completing a project at the end of the learning is the same as completing a project as a process for learning (see Tamim & Grant, 2013). As I have discussed project-based learning with colleagues throughout the process of this study, I have heard over and over: “Let’s do a project at the end or after the test, so students can show their learning in another way”
(i.e., teachers who use project-based learning as reinforcing prior learning or extending prior learning; Tamim & Grant, 2013). While I want students to think creatively and have opportunities to show their learning and thinking in different ways, a project at the end of the learning does not necessarily extend the learning. When project-based learning is used as a process for learning (i.e., as an initiator to learning; Tamim & Grant, 2013), students have more say in what they learn and how they learn. They work collaboratively, they think critically, they solve problems, and they share their learning with others in authentic ways. I think this change in thinking came for me when I saw the excitement for learning as we began the project. Students were excited to research and learn more about their animal motivating me to devote more time to the project. Parts of the project-based learning process are messy, and teachers need to be prepared for and plan for the times when things seem like they are not going well (Martelli, 2016). There were moments the students and I felt the process was taking a long time, but the end goal of sharing the learning kept us all motivated. Overall, project-based learning changed the way I look at teaching and learning.

**Unexpected findings.** As I began this project-based learning unit with my students, I could not predict what it would reveal. Overall, students enjoyed the process of learning and sharing, although some more than others. I thought students would enjoy getting out of the traditional lecture style teaching, where we learn science from the book and do not have much time left over for hands-on activities. I did not realize how much of an impact it would have on them and me.

One of my groups was composed of difficult students who have had behavior issues and learning issues. This project was the first time we used an Immersive Reader
with OneNote for students to have the information read aloud to them. It changed their whole outlook because now they were able to access the information just like everyone else. It was significant for my low readers, and I will use this feature as often as possible for my struggling readers from now on. Another positive outcome from this group was the level of learning that happened, which was evident in their performance and presentation (Ball, 2010). Their enthusiasm took them deep into the information available and they made sure they knew as much about their animal as possible. This depth of knowledge showed in their presentation to other students and parents. They shined because they were proud of their work and wanted to share it with as many other people as possible.

**Implications of project-based learning.** During this research, student engagement was increased during the process of learning within the project-based learning unit. Project-based learning implementation increases student engagement and motivation for science learning (Chia Liu et al., 2009). Students actually wanted *more* time to work on their projects than was available at times, and it was hard to tell them they could not work when they were so excited for learning. Other times, it seemed students were losing their enthusiasm for the project. When it seemed students were stuck, I found it was a good time to take a look around and reflect on what had been completed to that point. We took a look at what each other had done with their learning to that point. As a teacher, it is hard to say, “I don’t think this is working,” and stop and review where to go at that point.

Teacher reflection is part of evaluating the level of success for any lesson in the classroom. Reflection in the project-based learning process helps the teacher determine if
the intended learning is happening and if any adjustments need to be made. This evaluation of teaching and learning is one part of using inquiry to improve teaching methods (Mertler, 2017), in this case managing the learning in a project-based learning environment. As we progressed through each part of the process, I reflected on what the next steps needed to be for the success of students in the project. During the first phase of the project, the questioning phase, I observed and evaluated the previous knowledge and background information the students came to the project with. As we categorized the questions, I noticed students had a good bit of information about life cycle, food chain, and endangered animals. However, students did not have a good understanding of habitats and adaptations. This realization helped me to plan targeted mini lessons during the project to help students understand more about where and how animals live and how they survive in their environment. I was able to locate more digital information about both habitats and adaptations for animals in general but not specific to [state]. I also checked out some books from the school library on the specific animals’ students were studying to increase the number of resources. Some of the animals in which students were interested were not on the original list; this desire to learn convinced me to add the Key Deer and Flamingo to the list of animals.

Their reflection helped me to know how I could better help them learn the concepts being studied because I could understand from their work how well they understood the concepts and adjust learning opportunities as needed. So much can be learned by thinking about the work students are doing or the questions they are asking. This powerful tool gave me insight into how best to proceed from day to day within the scope of the project.
**Becoming a scholarly practitioner.** Conducting a review of literature related to technology integration, project-based learning, critical thinking, and motivation to learn science helped me to gain a knowledge of what has been done in the past for technology implementation and measurement of critical thinking and motivation. As I proceeded, I realized the importance of understanding what has been successful in the past and how that could inform my innovation and analysis of the innovation. As a scholarly practitioner, it is important to frame the current study in the existing literature to better understand and connect the results of the study. The review of literature allowed me to use an existing motivation survey (i.e., SMQ-II) and adapt it to my needs for greater reliability. Conducting the literature review and analyzing previous research led me to the constructivist approach for learning and ultimately project-based learning as a way for students to construct their knowledge. Past researchers’ frameworks (e.g., Grant, 2011; Blumenfeld & Krajcik, 2006; BIE, 2017) for project-based learning were a guide to the approach I took in designing my innovation. To determine the best path for my students, I considered the existing research and frameworks of project-based learning. When planning for learning, it is important to look at the context in which students are learning, including the content topic and setting. Sharing the outcomes of this research is one way to help other teachers and administrators understand the concept of project-based learning and how it can increase critical thinking in the classroom setting.

In summary, using this approach to designing learning for my students has changed the way I think and how I plan for my classroom. My review of the literature gave me insight into what had been attempted previously and how I could use it to benefit my students. I plan to incorporate active learning opportunities into my lessons as often
as possible keeping a mindset of activities for learning as opposed to learning to complete activities. Continuing my investigation of current and future research will help me implement new ideas and structures in my classroom. Doing this offers a way to help other teachers move toward an active learning environment by sharing the results of my findings. As I complete more project-based learning in the classroom, I will invite teachers to share in the experience by participating with my class or visiting my class as an audience after the completion of the unit. Evaluating my work and sharing with other practitioners can affect the active learning, motivation, and critical thinking skills for a larger population of students.

**Implications for Technology Integration**

Technology integration can add to the students’ learning experience in many different ways. There are many ways teachers can integrate technology in the classroom, including consumption of information, sharing of information, collaborating with others in the classroom or outside the classroom, and creating content. Two important aspects of technology integration in this study include (a) tools for collaboration and (b) tools for creation and sharing learning.

**Tools for collaboration.** Tools for collaboration can bring students closer together even if they are not in close proximity. Ease of use with multiple systems or technologies helped students to be successful in many different applications (Grant & Branch, 2005). In this study students used technology to collaborate on the planning and creation of their artifacts. For example, as students began to research information about their animals, they thought about how to organize the information. Some students created different sections in their composition notebooks to write information about each
concept, so when they came together, they could share in an organized way. As students began to discuss their information and decide how to best present the information, they found writing in one student’s notebook would not give everyone access to the information and planning later. As they looked for a solution, I directed them to a Microsoft Word document to keep track of their ideas, and I showed them how to create a different section for each concept they were sharing with each other. Students were all able to add to the Microsoft Word document and then discuss the ideas more easily because they were now organized by topic and included all the information they had gathered. After teaching one group, they became experts (Zawilinski, 2012) who were sought out for help as other groups wanted to learn how to accomplish the same organization and sharing abilities. Students shared the document with their group so everyone could access the information and have the ability to continue working even if one person was not there.

The shared Microsoft Word document also allowed students to document their thoughts and share them with me. I could then review the information and give feedback or provide direction as needed. Giving the teacher the ability to collaborate with students in real time as students work helps to speed the feedback process. If a group was on the wrong track, I could identify it immediately and give them assistance instead of them getting further into the project and having to back up several steps to correct the problem. When students worked and collaborated on their Microsoft PowerPoint educational presentations, they followed a similar process of sharing it with each other and me. I could then offer feedback on the amount and content of information guiding them to make an appropriate teaching tool to share with their audience.
Another tool used for sharing was Seesaw, a digital portfolio platform, where students posted their questions, shared their digital presentations, pictures of their habitat models, and their commercials advertising their exhibit. Posting questions on Seesaw allowed students to refer back to them at any point to examine the points raised by classmates. I shared items with students through Seesaw to speed the dissemination of information and resources. Another use of Seesaw was sharing digital presentations for other groups to see the information. Giving students the opportunity to use Seesaw as a way for students to give each other feedback could benefit the process of learning as well as the artifacts. Formative assessment was easy with Seesaw because students could create audio or video to explain and prove how they understood a concept. Seesaw offers the possibility to hear from each student in the class, giving all students a voice within the classroom.

To collect data from students for their science content assessment and critical thinking prompts, I used Google Forms. Collecting information from students in this manner allowed for ease of collecting this valuable data in a digital format that I could access from anywhere. Information can then be compiled in a Google Sheet spreadsheet with the ability to view graphs of the information. The use of Google Forms can be valuable in the classroom for collecting information about student understanding in a timely manner. I can quickly assess understanding for each question by looking at the graphs created from the spreadsheet.

Proper instruction on the use of tools is essential in technology integration. Students ran into issues throughout the process of learning and collaborating with technology. Several times students accidentally deleted all the information in their Word
document causing some stress to the members of the group. As students realized what happened and they could not figure out how to correct it, they came to me for help. In most instances I could recover their lost work and they were able to move forward. They then became eager to help others who had the same problem saying, “I can help them,” and rushing to be the hero. Several groups also had issues during the creation of their PowerPoint presentations, causing intense discussions of how it could have happened. For example, one group had all of the background colors change to black, no one wanted to admit to making this happen, but we were able to fix the issue and move forward. These more serious issues needed guidance to help think about the end goal and correcting the problem. When introducing new tools for use within the project, it was important to give a quick lesson on the basics of the tool. This type of scaffolding allowed me to anticipate issues that may arise from student use of technology and in some cases avoid those problems. The scaffolding process helped create a safe environment for students to experience new technology.

**Tools for creation and sharing.** I often see teachers use technology for consumption of information. Giving students exposure to a digital form of information makes teachers feel as though they are integrating technology when in fact, they are using technology as a replacement for a physical copy of the same material (PuenteDura, 2006). This is a common misconception among teachers who are hesitant to use technology. The SAMR model (PuenteDura, 2006) presents technology integration as either enhancement of transformation. Many teachers will venture into the substitution aspect of technology integration seeking to substitute technology for a task without changing the task itself. For example, teachers will offer students consumption of content in a digital format
without changing the content being consumed. When a task is redesigned or redefined because of the technology integration, teachers have transformed a task (Puente\textsuperscript{2}edura, 2006). A teacher’s comfort level with technology often determines the type of integration that occurs (Dooley et al., 2016).

TPACK combines knowledge of technology, pedagogy, and content to plan technology integration that addresses the standards being studied, how the standards are presented and learned, and the appropriate use of technology (Koehler, Mishra, & Cain, 2013). Technology cannot be the only consideration when planning lessons for students, the practitioner must also consider what teaching strategies are most effective for the learner and what content is to be learned. Effective technology integration should not be technology for the sake of technology use but technology as a way to enhance curriculum and instruction of content for effective student learning.

Student creation of content is one way students can show what they have learned when studying and learning about a topic (Blumenfeld et al., 1991; Grant, 2002; Krajcik & Blumenfeld, 2006). Creation as a way to show learning is one of the exciting aspects of technology integration. In this study, students created an educational presentation to show what they learned about their animals. They worked together to determine how best to present the information to an authentic audience who may or may not know about their animal (Defauw, 2014; Martelli & Watson, 2016). They took pride in their work because they knew someone outside our classroom would see the information; they worked to make sure the work was accurate because of this.
Implications for Project-Based Learning

Project-based learning offers an active learning environment where students have more control of their learning because the learning is centered on the student (Grant, 2011; Krajcik et al., 2000). The active inquiry environment created by project-based learning increases the interaction between content knowledge and critical thinking skills by encouraging students to deepen their thinking (Siew & Mapeala, 2016). Implications of project-based learning include suggestions regarding (a) teachers and (b) students.

**Teachers.** Teachers face new challenges every day in the classroom — from limited time and resources to more requirements for standardized testing. Teachers are hesitant to try new learning strategies because they are unfamiliar with them and may not understand how to successfully implement them (Tamim & Grant, 2013). Project-based learning and a constructivist approach can be a challenge for teachers because it is not as structured and at times it may feel like chaos (Grant & Hill, 2006). If a teacher is used to a structured, orderly classroom they have to shift their thinking in order to try this approach to learning. The project-based learning framework can offer a starting place for teachers to begin to understand how to plan and implement this learning. Projects can range from small to large and incorporate a few standards or many standards that cover a range of content areas.

Preparation for students who are unfamiliar with project-based learning need instruction or direction to understand how to navigate their way through this different type of learning environment. Ertmer and Simons (2006) suggest the use of posthole problems to help students understand the aspects of working and collaborating within a small group, which is appropriate for project-based learning units. This idea of smaller
projects to help students prepare to work in the project-based learning environment may help students practice for a different way of learning. Teachers may find it helpful to have smaller projects at the beginning of the school year as a way to show how learning can take place with peers and how students can have a voice and choice in their learning.

Students. 21st century skills are the skills students need to be successful in today’s world (The Partnership For 21st Century Skills, 2009). These skills include collaboration, communication, problem solving, and critical thinking. All of these skills can be developed through project-based learning by incorporating different content areas into a project where students learn through the development of ideas and artifacts that show learning (Bell, 2010; The Partnership For 21st Century Skills, 2009). In this study students used all of these skills to learn about and share information about their animal. Collaboration happened in a number of ways, including sharing research notes, planning and creating the animal’s habitat and Microsoft PowerPoint presentation, and sharing the learning with an audience. Students encountered problems throughout the learning experience and had to work through those situations by using negotiation and compromise. Critical thinking is woven into the thinking that students had to do when determining how to incorporate information into the learning outcome or artifact. Communication is one of the most important parts of learning. Students need to be able to communicate with each other, the teacher, and the audience they are sharing their learning with. An example of this from the study is illustrated in the student’s willingness to get on the level of the kindergarten students to communicate with them. They realized if they got on their level, they could address them more effectively. These 21st century
skills should have a place in all classrooms because these are the skills students will need as they navigate their world outside of the classroom.

Part of the process of learning in a project-based learning environment is to give students the opportunity to become accountable for their own learning and growth (Grant, 2002, 2011). Teachers can do this by helping students plan and carry out different parts of the learning process, navigate the waters of collaboration, and scaffold difficult parts of the process. The teacher is essential as a guide to students in helping them feel success as a learner and then challenge them to complete the next aspect of the project (Grant, 2011). Project management skills can be grown in this type of student-centered classroom environment (Meyer & Wurdinger, 2016). Students know what their tasks are, and they learn how to manage resources and time to accomplish the tasks within the learning process. In this study this management of learning was scaffolded by whole group and small group discussion of what had been completed, what was working, and what needed to be completed next. Students learned to evaluate what needed to be done during each working session to keep themselves on track.

The implications for student voice and choice are numerous. When students realize they have a voice and choice in how or what they are creating or learning they grasp that they have a sense of control over their own learning (Ball, 2016; Fahey & Cronen, 2016). In this study, students were able to choose which animal to research and how to complete each part of the project in this study. Student interest was high because they each chose the animal that was interesting to them. I had to add animals to the original list to accommodate for student interest. As we progressed through the project, students had the opportunity to represent their artifact in the way they wanted within the
parameters of creating a habitat model and a digital educational presentation. For the purpose of this project, students were required to complete both artifacts. Their choice and voice came in how they represented different aspects of each artifact. Some students were more methodical about creating their habitat model and others wanted to experiment with different materials to create elements of the environment. For example, the manatee group wanted to get sand from the playground for the bottom of their habitat, they couldn’t believe it when I told them yes and sent them outside. This was a turning point for some of the students because they could see they had some control in their project.

Sharing learning with an audience outside of the classroom gives students the feeling of purpose in their learning (Chen & Brown, 2012). Usually in the classroom setting, students share their learning with their teacher for the resulting grade; the work may then be seen by parents. While completing work to show growth is important, the teacher is an audience of one who is viewing the provided information for the purpose of grading it. Some students thrive on the grades they receive and will work for those grades even if the only person viewing their work is the teacher (Grant, 2011; Vedder-Weiss & Fortus, 2012). Other students are not motivated by grades (Bell, 2010). Sharing work with a greater audience can help motivate these students and keep them accountable for their work (Bell, 2010; Defauw, 2014). As a teacher I want to find ways to reach all students by offering a variety of ways to engage students in learning and sharing their learning.

Students in this study knew from the beginning that the audience would be a group of kindergarten students, administration, school staff, and the students’ parents. Keeping this in mind helped my students have direction for their work (Defauw, 2014).
Students would ask themselves or I would ask them if certain content was appropriate for the intended audience. The students then had to think about the impact of what they were producing. The educational presentations were shared with visitors to the exhibit, and they were shared on Seesaw for viewing by parents who could not make it to the presentation day.

**Implications for Future Research**

The finding of this study offers implications for future research by teachers and researchers. Teachers who are looking to implement technology or project-based learning in their classroom or school may be interested in future research related to these topics.

If I were to replicate this study in my classroom, I would make several changes and adjustments. Cycle two of this action research in my classroom would include an assessment of technology as a motivator in the process of learning. I would include motivation reflection questions to assess student motivation to learn science within the project-based learning unit to strengthen the results of motivation to learn science content. I would also include student interviews to ask students their thoughts on how technology enhanced their learning experience. Another change for the second cycle of this study would include revising the science content knowledge assessment. After evaluating the test items, I would remove some questions that were not as clearly written and replace or revise them to more accurately assess the standard. The reliability of the assessment ($\alpha = .58$) was weak (DeVellis, 2003), and revision to the test items could improve the quality of the assessment. A revision of the digital educational presentation would include content specific vocabulary and a more thorough description of
requirements. Another critical thinking prompt at the end of the process would benefit the overall picture of student critical thinking.

Replicating this study across all fourth-grade classrooms at the school could give a broader view of the effects of project-based learning over a larger population of students. Having a larger body of data would help to determine the effects of technology integrated project-based learning on fourth grade students and specifically to the science content. The study could determine if technology integration increased motivation to learn and how critical thinking skills were used and developed by students in the project-based learning environment.

Following students through several years of project-based learning in science content (i.e., a longitudinal study) could help determine if project-based learning creates a deeper connection for students with science concepts. Students could begin in third grade and participate in science related project-based learning units through fifth grade. Fifth grade students participate in standardized testing for science. This study could use the data collected each year of the study in conjunction with the data from the standardized testing to determine if student performance increased compared to previous years or compared to schools who used a more traditional approach to science teaching.

Completing multiple projects throughout the year could help students build stamina for and understanding of the project-based learning process. Starting earlier in the year with a posthole project (Ertmer & Simons, 2006), or short mini project-based learning unit, helps students learn the skills necessary to be successful in an active inquiry classroom (Grant & Hill, 2006). Giving students the opportunity to practice these
skills on a smaller scale gives them confidence as they move on to larger scale projects that could span weeks.

**Limitations**

As with all action research, there are limitations that should be noted. Action research is designed to answer specific problems of practice in specific contexts (Mertler, 2017). Findings of this action research are limited by the context of my classroom. The small sample size is a limitation because one class may not be representative of the whole grade level or students attending neighboring schools. This study consisted of one class of 26 students, all of whom participated in the innovation. There was no control group for comparing data. This study, while providing insight on technology integrated project-based learning, cannot be generalized beyond this context. Insight beyond the context of this study is made at the discretion of the reader.

Another limitation of this study includes the instruments used. The rubric used to evaluate the final digital educational presentation had one section that needed to be removed due to the outcomes of the study. Students were originally scheduled to examine the adaptations of plants, as well as animals. The study went more in the direction of animal adaptations; therefore, the plant adaptation section of the rubric was removed. One item on the motivation to learn science survey, “I like to do better than other students on science tests,” was confusing to students because it implied, they wanted their classmates to do poorly on assessments. Students looked at it as a negative concept and scored it lower on the Likert-type scale because of this. A redesign of this question would be necessary for future research. Finally, I would include an additional critical thinking prompt for after the completion of the study. I would ask students, “How did this project
change how you think and learn?” This question could give me insight into the overall success of the project along with student thoughts about elements that helped them throughout the process.

Another limitation to this study is the interruptions faced in my school setting. Many interruptions happen throughout the course of the school year. This study was carried out in the Spring, which included Spring break and state testing. These interruptions caused a slow-moving process at times and a hurry up feeling at others. Students wanted to work on their project at times and were unable to because of competing technology needs within the school, which prevented our access to the laptop computers. Since we were limited to when the laptop cart could be checked out for our class, we had to work around the needs of other classes within the school. Part of testing in the school required the use of the laptops cart, so we had to be strategic in when we could work on the project. Another interruption came during state testing time. State testing requires long periods of time to be dedicated to the test leaving less time in the day to dedicate to the project. Absences became an interruption that affected many groups, but one group in particular had multiple students absent repeatedly. The absences hindered the progress of this one group more than the others because they did not have many opportunities to discuss the progress of their project. All of these interruptions are indicative of authentic everyday schooling; however, they may have impacted the findings.

**Closing Thoughts**

Creating students who are lifelong learners capable of critical thinking to solve problems has been a goal of mine throughout my career. With the increase in mandated
testing and a focus on teaching as a path to passing a test, teachers feel more pressure to help students achieve higher scores. As this inundation of testing has risen, I have looked for new and innovative ways to help students succeed in learning and build confidence in who they are as people not just having a score determine who they are or what they can do. Students need to be actively involved in their own learning process and understand why and how what they are learning applies to the world around them. I am constantly amazed by what students are capable of and how willing they are to try new things when they know there is someone there supporting them, allowing them to make mistakes and try again. Project-based learning is one method for allowing students to find out what they are capable of and push them to share their learning with others in order to improve themselves.

Technology integration as part of the learning process can bring the world inside the classroom and the classroom to the world. Students can use technology as consumers at an early age, and it is the job of educators to teach them how they can use technology to become creators. When we share the possibilities of what technology can do to bring the world to students, it opens possibilities for students to explore things they did not know existed.

As I reflect back on the process of learning during this technology integrated project-based learning experience I can see how it changed me as an educator and how that in turn changed the future for my students. The skills students learned from working together toward a shared goal will be taken into the rest of their learning career and beyond. The information I have gained will help me provide better experiences for my future students.


https://doi.org/10.1080/15391523.2010.10782551


https://doi.org/10.1080/00098655.2016.1170450


https://doi.org/10.1002/tea.21136


*Contemporary Educational Psychology, 54*(May), 42–54. 
https://doi.org/10.1016/j.cedpsych.2018.05.004


Harris, M. J. (2014). *The challenges of implementing project-based learning in middle schools.*


APPENDIX A

UNIVERSITY OF SOUTH CAROLINA
CONSENT TO BE A RESEARCH SUBJECT
The Effects of Technology Integrated Project-Based Learning on 4th Grade Students

You and your child are invited to volunteer for a research study conducted by Diane Lawson. I am a doctoral candidate in the Department of Curriculum and Instruction, with emphasis in educational technology. The University of South Carolina, Department of Educational Studies is sponsoring this research study under the direction of Dr. Michael Grant. The purpose of this action research is to describe the impact of technology integrated project-based learning on students critical thinking, motivation to learn science content, and science content knowledge at Firebird Academy. Your student is being asked to participate in this study because he/she is in Mrs. Lawson’s fourth grade class. This study is being done at Firebird Academy and will involve approximately 26 volunteers.

As part of the “Habitats and Adaptations” project-based learning unit students will choose an animal to research from a list of native state animals, create a model of the animal’s habitat, a presentation to educate others about the animal’s habitat and adaptations, and share what they have created with an audience. Learning content and the essential question will be based on state standards for fourth grade: Science heredity and interdependence standards, and English Language Arts writing, reading and speaking standards.

This form explains what you will be asked to do, if you decide to participate in this study. Please read it carefully and feel free to ask questions before you decide about participating.

If you agree to participate in this project-based learning study, you will do the following:

- Pre and post survey data will be collected for motivation to learn science
- Pre and post assessment data will be collected for science content knowledge
- Reflection responses will be collected throughout the study
- Descriptive statistics will be collected for the artifacts using a rubric
Participation in the study involves participating in project-based learning classroom activities during science, reading, and writing blocks during a 2-3-week time frame in the Spring of 2019.

No risks are anticipated with this classroom research. All student responses and reflections will be confidential. Student names will be changed to protect their identity. Research data will be kept in password protected files to ensure confidentiality.

Participation in this research study is voluntary. Your child is free not to participate, or to stop participating at any time, for any reason without negative consequences. In the event that your child does withdraw from this study, the information s/he has already provided will be kept in a confidential manner. If you or your child wish to withdraw from the study, please call or email Diane Lawson.

If I have any more questions about my participation in this study, or a study related injury, I am to contact Diane Lawson, ___

Questions about your rights as a research subject are to be directed to, ___

I have been given a copy of this form for my own records.

Since this is part of everyday classroom research, if you wish for your child’s data not to be included in my research, please sign below.

__________________________  _______________________
Signature of Parent/ Guardian            Date

__________________________  _______________________
Diane Lawson, Doctoral Candidate/Researcher            Date
APPENDIX B

PRE- POST MOTIVATION TO LEARN SCIENCE SURVEY

Motivation in Science Learning
The purpose of this questionnaire is to help your teacher understand your motivation to learn science content before project-based learning and after project-based learning. Please choose the number using the code below that describes how much you agree with each statement.

* Required

1. First Name *

2. Last Name *

3. Motivation in Science Learning *
Mark only one oval per row.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neutral</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learning science is interesting.</td>
<td>〇</td>
<td>〇</td>
<td>〇</td>
<td>〇</td>
<td>〇</td>
</tr>
<tr>
<td>I am curious about discoveries in science.</td>
<td>〇</td>
<td>〇</td>
<td>〇</td>
<td>〇</td>
<td>〇</td>
</tr>
<tr>
<td>The science I learn is relevant to my life.</td>
<td>〇</td>
<td>〇</td>
<td>〇</td>
<td>〇</td>
<td>〇</td>
</tr>
<tr>
<td>Learning science makes my life more meaningful.</td>
<td>〇</td>
<td>〇</td>
<td>〇</td>
<td>〇</td>
<td>〇</td>
</tr>
<tr>
<td>I enjoy learning science.</td>
<td>〇</td>
<td>〇</td>
<td>〇</td>
<td>〇</td>
<td>〇</td>
</tr>
<tr>
<td>Scoring high on science tests and labs matters to me.</td>
<td>〇</td>
<td>〇</td>
<td>〇</td>
<td>〇</td>
<td>〇</td>
</tr>
<tr>
<td>It is important that I get an &quot;A&quot; in science.</td>
<td>〇</td>
<td>〇</td>
<td>〇</td>
<td>〇</td>
<td>〇</td>
</tr>
<tr>
<td>I think about the grade I will get in science.</td>
<td>〇</td>
<td>〇</td>
<td>〇</td>
<td>〇</td>
<td>〇</td>
</tr>
<tr>
<td>Getting a good science grade is important to me.</td>
<td>〇</td>
<td>〇</td>
<td>〇</td>
<td>〇</td>
<td>〇</td>
</tr>
<tr>
<td>I like to do better than other students on science tests.</td>
<td>〇</td>
<td>〇</td>
<td>〇</td>
<td>〇</td>
<td>〇</td>
</tr>
</tbody>
</table>

https://docs.google.com/forms/d/e/1FAIpQLSdclOX39g2ksONJZihN5YtYcJE_UYJjXUIUOSRin-8siddOg/viewform?usp=pp_url
APPENDIX C
PRE-POSTASSESSMENT STANDARDS ALIGNMENT

State Standard Alignment: Habitats and Adaptations

<table>
<thead>
<tr>
<th>State Standard</th>
<th>Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>SC.4.L.16.2 Explain that although characteristics of plants and animals are</td>
<td>1. One kind of moth lives on the bark of trees. In areas where the trees and moths are located near factories, their color is dark. Where</td>
</tr>
<tr>
<td>inherited, some characteristics can be affected by the environment.</td>
<td>there are no factories, the same kinds of moths and trees are light colored. What is the most likely cause for this change in color?</td>
</tr>
<tr>
<td></td>
<td>2. The mahogany tree that grows in southern produces seeds that look like this. Notice the blades on the surface of the seed. What role</td>
</tr>
<tr>
<td></td>
<td>do these blades play in the life cycle of the mahogany tree?</td>
</tr>
<tr>
<td></td>
<td>3. An arctic hare is brown in the summer and white in the winter. What is the most likely cause of this change?</td>
</tr>
<tr>
<td></td>
<td>4. An animal’s environment can change some of its physical traits. Which trait can be changed by the environment?</td>
</tr>
<tr>
<td></td>
<td>5. Sameh looks a lot like other members of his family. Which is a trait that Sameh probably did not inherit from his parents?</td>
</tr>
<tr>
<td></td>
<td>6. The arctic hare has brown fur during warm months. During cold months, the hare’s fur changes to white, as shown in the picture below.</td>
</tr>
<tr>
<td></td>
<td>What is the main advantage of the hare’s white fur?</td>
</tr>
<tr>
<td></td>
<td>7. Each year, humpback whales travel from Alaska to Hawaii. What is the correct word for this process?</td>
</tr>
<tr>
<td>State Standard</td>
<td>Questions</td>
</tr>
<tr>
<td>-------------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------</td>
</tr>
<tr>
<td>SC.4.L.16.3 Recognize that animal behaviors may be shaped by heredity and learning.</td>
<td>1. A characteristic that helps a living thing survive.</td>
</tr>
<tr>
<td></td>
<td>2. Monarch butterflies migrate to warm places every winter. What causes this?</td>
</tr>
<tr>
<td></td>
<td>3. Animals in the wild learn to do many things. When do most animals learn their behaviors?</td>
</tr>
<tr>
<td></td>
<td>4. Parents pass on traits to their children. What are traits?</td>
</tr>
<tr>
<td></td>
<td>5. The picture below shows a [underline] panther stalking its prey. Where does the panther learn this behavior?</td>
</tr>
<tr>
<td>SC.4.L.17.2 Explain that animals, including humans, cannot make their own food and that when animals eat plants or other animals, the energy stored in the food source is passed to them.</td>
<td>1. Dora needs to complete the chart below. Which statement belongs in the Producers column?</td>
</tr>
<tr>
<td></td>
<td>2. Some organisms break down dead things for food. Which word describes these organisms?</td>
</tr>
<tr>
<td>SC.4.L.17.3 Trace the flow of energy from the Sun as it is transferred along the food chain through the producers to the consumers.</td>
<td>1. The picture below shows a food chain. What is the main source of energy for this food chain?</td>
</tr>
<tr>
<td></td>
<td>2. Iguanas are lizards that eat plants and insects. What kind of consumer is the iguana?</td>
</tr>
<tr>
<td>SC.4.L.17.4 Recognize ways plants and animals, including humans, can impact the environment.</td>
<td>1. Deshad reads a book about the [underline] manatee. He learns that the manatee is a threatened species. What is the greatest threat to the manatee in [underline]?</td>
</tr>
<tr>
<td></td>
<td>2. The place where a living thing lives.</td>
</tr>
</tbody>
</table>
APPENDIX D

PRE-POSTASSESSMENT: HABITATS AND ADAPTATIONS

Habitats and Adaptations

Answer the following questions to represent your knowledge of habitats and adaptations.

* Required

1. First name

2. Last name

3. One kind of moth lives on the bark of trees. In areas where the trees and moths are located near factories, their color is dark. Where there are no factories, the same kinds of moths and trees are light colored. What is the most likely cause for this change in color? *

SC.4.L.16.2

Mark only one oval.

- det
- instinct
- environment
- learned behavior

4. The mahogany tree that grows in southern Florida produces seeds that look like this. Notice the blades on the surface of the seed. What role do these blades play in the life cycle of the mahogany tree? *

SC.4.L.16.2

Fan-like blades

Mark only one oval.

- protect the seed
- ends the plant’s life cycle
- store food for the seedling
- produce pollen for sexual reproduction
5. An arctic hare is brown in the summer and white in the winter. What is the most likely cause of this change? *
   SC.4.L.16.2
   Mark only one oval.
   - learned behavior
   - instinctive behavior
   - effect of environment
   - beginning of hibernation

6. An animal’s environment can change some of its physical traits. Which trait can be changed by the environment? *
   SC.4.L.16.2
   Mark only one oval.
   - gills on a tadpole
   - stripes on a zebra
   - color of a pink flamingo
   - type of hair on a dog’s coat

7. The arctic hare has brown fur during warm months. During cold months, the hare’s fur changes to white, as shown in the picture below. What is the main advantage of the hare’s white fur? *
   SC.4.L.16.2
   ![Arctic Hare](image)
   Mark only one oval.
   - It stops the hare from losing water.
   - It reduces the amount of food the hare needs.
   - It helps the hare remain warm.
   - It is harder for predators to see the hare.

8. Sameh looks a lot like other members of his family. Which is a trait that Sameh probably did not inherit from his parents? *
   SC.4.L.16.2
   Mark only one oval.
   - size of his feet
   - shape of his ears
   - color of his eyes
   - length of his hair
9. Each year, humpback whales travel from Alaska to Hawaii. What is the correct word for this process? *
   SC.4.L.16.2

Mark only one oval.
- migration
- adaptation
- hibernation
- reproduction

10. A characteristic that helps a living thing survive. *
    SC.4.L.16.3
    Mark only one oval.
    - adaptation
    - migration
    - life cycle
    - habitat

11. Monarch butterflies migrate to warm places every winter. What causes this? *
    SC.4.L.16.3
    Mark only one oval.
    - trait
    - instinct
    - characteristic
    - learned behavior

12. Animals in the wild learn to do many things. When do most animals learn their behaviors? *
    SC.4.L.16.3
    Mark only one oval.
    - when they are born
    - when they are adult
    - when they are young
    - when they get a reward
13. **Parents pass on traits to their children. What are traits?** *  
**SC.4.L.16.3**  
Mark only one oval.  
- genes  
- instincts  
- learned behavior  
- physical features

14. **The picture below shows a Florida panther stalking its prey. Where does the panther learn this behavior?** *  
**SC.4.L.16.3**

![Picture of Florida panther stalking prey]

Mark only one oval.  
- by itself  
- from its mother  
- from its instincts  
- from other panther cubs

15. **Dora needs to complete the chart below. Which statement belongs in the Producers column?** *  
**SC.4.L.17.2**

<table>
<thead>
<tr>
<th>Facts about...</th>
<th>Consumers</th>
<th>Producers</th>
<th>Decomposers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Mark only one oval.  
- eat plants  
- eat animals  
- use photosynthesis  
- break down dead material

16. **Some organisms break down dead things for food. Which word describes these organisms?** *  
**SC.4.L.17.2**  
Mark only one oval.  
- consumers  
- herbivores  
- decomposers  
- producers
17. The picture below shows a food chain. What is the main source of energy for this food chain? * 

SC.4.L.17.3

Mark only one oval.

- hawk
- mouse
- plants
- snake
18. Iguanas are lizards that eat plants and insects. What kind of consumer is the iguana? *  
   SC.4.L.17.3  
   Mark only one oval.  
   □ carnivore  
   □ omnivore  
   □ herbivore  
   □ producer  

19. Deshad reads a book about the Florida manatee. He learns that the manatee is a threatened species. What is the greatest threat to the manatee in Florida? *  
   SC.4.L.17.4  
   Mark only one oval.  
   □ not enough food  
   □ being hit by a motorboat  
   □ chemicals in the water  
   □ crossing from fresh water into salt water  

20. The place where a living thing lives. *  
   SC.4.L.17.4  
   Mark only one oval.  
   □ adaptation  
   □ life cycle  
   □ habitat  
   □ camouflage  

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# APPENDIX E

## CRITICAL THINKING REFLECTION PROMPTS

<table>
<thead>
<tr>
<th>Reflection Prompts</th>
<th>Elements of Thought</th>
</tr>
</thead>
<tbody>
<tr>
<td>How did you determine what information to gather?</td>
<td>Information: All reasoning is based on data, information, and evidence.</td>
</tr>
<tr>
<td>• How did you determine what information to gather?</td>
<td>Question: All reasoning is an attempt to figure something out, to settle some question, to solve some problem.</td>
</tr>
<tr>
<td>• How did you use the information gathered from your research to inform the plan and creation for your habitat?</td>
<td>Concepts: All reasoning is expressed through and shaped by concepts and ideas.</td>
</tr>
<tr>
<td>• How did you use the information gathered from your research to inform the plan and creation for your educational presentation?</td>
<td></td>
</tr>
<tr>
<td>Describe a time when you and your teammates did not agree on how to proceed with your project:</td>
<td>Point Of View: All reasoning is done from some point of view.</td>
</tr>
<tr>
<td>• What did you disagree about?</td>
<td>Information: All reasoning is based on data, information, and evidence.</td>
</tr>
<tr>
<td>• Why did you disagree?</td>
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<tr>
<td>• How did your behavior change when they did not agree with you?</td>
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<tr>
<td>• What information did you use to solve the problem?</td>
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</tr>
<tr>
<td>Describe a time when you had difficulty completing part of the project:</td>
<td>Information: All reasoning is based on data, information, and evidence.</td>
</tr>
<tr>
<td>• What part did you have difficulty with?</td>
<td>Interpretation and Inference: All reasoning contains inferences or interpretations by which we draw conclusions and give meaning to data.</td>
</tr>
<tr>
<td>• Why was it difficult?</td>
<td></td>
</tr>
<tr>
<td>• How did you use information from your background, research, or teammates to find a way to overcome your difficulty?</td>
<td></td>
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</tbody>
</table>
Habitats and Adaptation: The Animals and Plants of Our State

<table>
<thead>
<tr>
<th>Project Expectation</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>Feedback</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demonstrate understanding of plant adaptations based on environmental changes, heredity, and learning.</td>
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<tr>
<td>Demonstrate understanding of animal adaptations based on environmental changes, heredity, and learning.</td>
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<tr>
<td>Vocabulary related to adaptations, environmental changes, heredity, and learning is used in the presentation.</td>
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<tr>
<td>Describe how an animal’s habitat is affected by humans and other animals.</td>
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<tr>
<td>Describe how an animal gets energy from the resources in its habitat (flow of energy).</td>
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<tr>
<td>Vocabulary related to habitats, food chains, and environmental changes is used in the presentation.</td>
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</tbody>
</table>

3 - Above expectations  2 - Meets expectations  1 - Below expectations