Impact of the Engineering Design Process on Rural Female Students’ Achievement and Self-Efficacy

Whitney Lowery Oberndorf

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IMPACT OF THE ENGINEERING DESIGN PROCESS ON RURAL FEMALE STUDENTS’ ACHIEVEMENT AND SELF-EFFICACY

by

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DEDICATION

To my grandfather, Tommy Ellis, who I lost during this journey - to say that your curiosity and stubbornness are missed is an understatement. This one is for you.

To my children, you have taught me more about life than I will ever be able to teach you. I hope that you never lose your sense of wonder, that you are always yourself, and that you never forget how loved you are. To my husband, you have always been home to me. To my parents and grandparents, who raised me to never give up and have always loved me unconditionally. There would be no me without each of you.
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ABSTRACT

Nearly one-fifth of U.S. children attend rural schools; however, these students have fewer opportunities for high-quality STEM learning. Rural students are also less likely to attend college and less likely to enroll in STEM majors than their urban and suburban peers. In conjunction with these factors, female students are also less likely to pursue STEM degrees and work in STEM fields. Broadening access and exposure to these areas, as well as improving female perceptions about STEM fields, is critical to closing the gap. This mixed-methods action research study was an effort to increase female achievement and self-efficacy in science and engineering. This study focused on the use of the engineering design process with fifth-grade, rural, female students. Findings indicate the engineering design process had a positive impact on achievement and self-efficacy in science and engineering.
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CHAPTER 1: INTRODUCTION

Two decades ago, during sophomore year, a teenage girl enrolled in a computer engineering course that had recently been implemented in her rural high school. She felt the new offering held promise and could open doors to future opportunities and introduce her to content she had never experienced as she was beginning to formulate potential college majors. She was the only young woman in the class and the experience proved to be less than appealing; she found her assigned tasks mundane, simple, and often administrative while the instructor expected male students to focus more on the problem-solving aspects of the engineering curriculum. She even enrolled in the second part of the course in a subsequent term to give it a second chance, but to no avail. Academically, she gave up on the prospect of pursuing a career in engineering and determined that it was not for her.

Later during the same school year, the student completed general Biology, a required course. Her teacher was passionate about the content and provided inquiry-based activities far beyond the scope of the scientific method that had previously engulfed the students' science education. Placed in an all-male group for dissections and other exploratory activities, she perceived her male classmates to be lackadaisical and disinterested; she considered this a stroke of luck as she was able to fully explore activities without any pushback from her group members. She became immersed in the course and excelled. She was challenged academically and as the teacher noted her enthusiasm and determination, she continued to push her limits and feed her curiosity.
After graduation, that girl from a one-stop-light hometown in the United States completed her undergraduate degree in Biology before earning her Master’s in Biological Sciences and Curriculum and Instruction. She focused on a career in education and has always credited that Biology course as a driving force in her endeavors. I can attest to her ambitions because I was that girl.

My lived experiences as a student and professional experiences as an educator, paired alongside my role as a military spouse since the onset of my teaching career, have afforded me the ability to understand issues that are widespread. My experiences have also provided me with a broader perspective of challenges in STEM education, especially gender disparities in rural communities.

**Problem of Practice**

While women make up almost half of the national workforce (48%), they only account for roughly one quarter of the STEM workers (27%), primarily working in social science occupations with low representation in computer and engineering fields (Martinez & Christnacht, 2021). Underlying reasons for the lack of women in STEM fields include: traditional gender roles led by social norms and infrastructure, lack of mentors or role models in such areas, and a general lack of understanding about these areas (Quinton, 2014). Research indicates that women have lower motivation than male students in STEM domains (Schiefer et al., 2021). In a study of high school students, Sadler et al. (2012) found that STEM career interest throughout high school was linked to initial interest when beginning high school and that interest declined among female students (15.7% to 12.7%) while it remained constant for male students. Mosatche et al. (2013) argued that female students show less interest in mathematics and science areas
and have a lower confidence in their math abilities in elementary school. As an educator, I have recognized the differences among male and female students in math and science interest, regardless of location or any other demographic factor.

Research suggests educators should “create a classroom environment that sparks initial curiosity and fosters long-term interest in math and science” (Halpern et al., 2007, p. 23). Integrative STEM education has the ability to motivate students to pursue STEM careers as well as improve both their interest and academic performance in science and mathematics (Stohlmann et al. 2012). Integrative STEM education is an approach that explores “teaching and learning between/among any two or more of the STEM subject areas, and/or between a STEM subject and one or more other school subjects” (Sanders, 2009, p. 21). As Wells (2016) noted, integrative STEM education is a “pedagogical approach for supporting knowledge construction through student engagement in technological/engineering design-based learning” (p. 12).

Rural schools lack financial support and resources which leads to the forfeit of high-quality educational programs, decrease in highly qualified teachers, and higher dropout rates (Peters Burton et al., 2014). Integrated, inquiry-based curricula that promote a learner-centered environment (Blessinger & Carfora, 2015) seldom exist in rural schools due to a lack of physical resources and a lack of teachers who are confident in their abilities to teach such curricula (Harris & Hodges, 2018). Inquiry-based, problem-solving curricula include student-led, exploratory activities that generally begin with a problem scenario and allow students to utilize resources to address the problem they have encountered through discovery, investigations, and research approaches (Blessinger & Carfora, 2015).
Makerspace learning environments serve as a basis for implementing the engineering design process in elementary classrooms. Defined as “constructionist learning environments” (Keune & Peppler, 2019, p. 281) in which students use an array of materials and tools to engage in hands-on activities and creative problem solving (Dougherty, 2012; Morado et al., 2021), makerspaces enable students to carry out the engineering design process. Such environments provide a workspace for individuals to collaborate and develop ideas, meeting learners’ diverse interests and needs (Morado et al., 2021). Students’ lack of familiarity and exposure to lessons that require collaboration and the development and use of critical thinking skills have led to academic struggles when making decisions in multi-faceted situations and applying creative thinking (Sias et al., 2017). Relevant research supports that student engagement with design problems in makerspaces encourages creativity and learning (Hatzigianni et al., 2020). Numerous studies have also identified positive correlations between academic achievement and creativity (Gajda et al., 2017; Karwowski et al., 2020).

Rural school districts seldom budget for learning experiences that require both consumable materials and durable equipment. However, research shows that rural communities have just as much potential for success as their urban and suburban counterparts. Connecting to local culture and utilizing real-world problems to teach academic content amplifies students' performance (Harris & Hodges, 2018). Exposing students to STEM areas through personal experiences and academic coursework is likely to increase their pursuance of these areas in higher education (Elam et al., 2012). Sias et al. (2017) suggested classroom coursework is generally deficient in computational thinking and reasoning, vital STEM skills. The Engineering Design Process (EDP) is
defined as a “flexible framework that organizes how inventors and engineers ask questions, build and test prototypes, seek solutions to problems, and communicate results” (Jackson et al., 2021, p. 26). Howes (2002) argued that engineering design engages children and contextualizes their learning within. Hill-Cunningham et al. (2018) noted that the EDP engages students in a manner that allows them to understand multiple viewpoints, solve problems, and act as actual engineers.

While limited research exists specific to the participants and context of this study (i.e., rural, supper-elementary girls), relevant research has found that rural female students continue to face educational barriers even as they progress into post-secondary education (Johnson, 2014). Students in rural communities may question the relevance of the EDP and makerspace environments to their own communities (Burnzpete et al., 2018; Kannapel & DeYoung, 1999).

State assessment data for the school in which this study is situated, The Point Elementary (pseudonym), demonstrates a critical need for female students in science achievement. For the 2021-2022 school year, fifth-grade female students had a 47.83% pass rate on the end-of-year science assessment compared to an 82.76% pass rate for their male counterparts ([State] Department of Education, 2022b). In response, I implemented an EDP innovation in fifth grade science classrooms to address low female academic achievement in science and engineering content areas as well as understand the impact of the EDP on these students’ science and engineering self-efficacy.

**Theoretical Framework**

This research is situated in the theoretical framework of constructivism, constructionism, and situated learning theory.
Constructivism

Constructivism was developed in 1964 by Piaget and focused on the idea that people, especially children, construct knowledge through their actions with their environment (Harlow et al., 2006). Piaget argued that children learn by connecting new knowledge to existing knowledge (Clark, 2018). When students encounter something that they cannot classify into an existing schema, they develop new knowledge by building on the foundation of prior knowledge. Constructivism focuses on how learning develops over time, in stages and how knowledge is refined within an individual (Austin, 2017). Piaget’s theory also emphasizes children’s actions within their environment, which they use to construct knowledge as children learn through experiences and interactions with their surroundings (Harlow et al., 2006). Makerspaces consistently allow engaging opportunities for students to meld previous knowledge and become aware of new knowledge, therefore making connections between previous and new knowledge (Andrews et al., 2021). Using a constructivist approach in teaching and learning, making can lead to deeper learning and understanding of academic concepts (Konstantinou et al., 2021; Parmaxi & Zaphiris, 2014).

Constructionism

Developed by Papert in the 1980s, constructionism emphasizes that learning occurs when people construct artifacts they can share and discuss with others (Kretchmar, 2014). Constructionism supports the notion that learning occurs most effectively when a learner partakes in an experience and creates something meaningful (Hatzigianni et al., 2020); the EDP allows students to create such products. This framework supports a student-centered, discovery-based approach to learning that allows students to learn by
making and building from background knowledge they already have acquired (Li et al., 2016). Research with young children in a makerspace setting supported this theory by showing that students were able to transition from merely learning scientific knowledge to being able to engage with this learned knowledge to develop new ideas and skills (Hatzigianni et al., 2020). Constructionism is rooted in allowing individuals to create using their own thought processes and harness control over much of their decision making (Schad & Jones, 2020). Stewart (2020) indicated that children may be more motivated to learn through the building process because they may consider it more authentic.

**Situated Learning Theory**

Developed by Lave and Wenger in 1991, situated learning theory argues that learning is a social process and students learn by participating directly in the learning experience. Stein (1998) contended that students learn when they are able to create meaning from real-life activities such as field trips, cooperative education, engagement in work environments, and laboratories. Within these contexts, students are an active part of the learning environment and are immersed in the process of learning. Situated learning allows students to explore prior knowledge and make connections between new ideas while utilizing fellow members of the classroom community. Situated learning is founded in the idea that situations that engage learners in applicable, problem-centered activities and learning opportunities will help students to learn best (Stein, 1998). This immersion into the learning environment is indicative of makerspaces environments and design problems are based on real-world, relatable problems that immerse students into the learning process.
Each of these lenses provided a different perspective on the same area of concern (Grant & Osanloo, 2014) and informed the makerspace environment that optimized student learning. The three theories situated the context of the EDP by allowing students to build on prior knowledge and construct new knowledge (Andrews et al., 2021), create through the application of content knowledge, and actively interact within a space to solve a problem. Constructivism, constructionism, and situated learning theory intersect to provide the theoretical foundation for makerspaces that engage students in the EDP to solve real-world problems and participate in inquiry-based learning.

**Purpose of the Study, Research Questions, and Rationale**

The overarching purpose of this research was to improve achievement in science and engineering learning for fifth-grade girls in a rural district by using the EDP in a makerspace-style classroom environment. I also aimed to measure the effectiveness of the EDP on improving science and engineering self-efficacy.

This research addressed two research questions as follows:

1. How can use of the EDP improve rural, fifth-grade girls’ achievement in science and engineering standards?

2. What is the effect of female students’ use of the EDP on their science and engineering self-efficacy?

The research questions arose from observation and analysis of female students in science classrooms and student performance on standardized tests. The questions are designed to measure the implementation of the EDP and determine its effect on students’ achievement and self-efficacy. The state employs a series of learning standards that throughout elementary school focus on varying areas of science content with integrated
engineering practices. Makerspace environments allowed opportunities to utilize the EDP and further develop students understanding of scientific and engineering practices in application.

Data from the 2021–2022 Standards of Learning Science assessment, a standardized state assessment, show that overall, female students perform lower than male students in both fifth- and eighth-grade science standards; eighth-grade data support a low percentage of passing for scientific investigation standards—those that directly relate to engineering and technology practices. Previous solutions to assist in conceptual understanding of science content and an increase in science, technology, and engineering performance include a shift from scientific reasoning and logic via investigations to the use of science and engineering practices to understand science standards. The district has also implemented a program of videos and use of online programs with videos and questions to further attempt to improve science achievement. These solutions have not made a measurable impact on standardized testing scores or an observational change in female students’ engagement in the classroom, thus necessitating this study.

**Positionality**

Positionality refers to the way that researchers “position themselves as insiders or outsiders” (Herr & Anderson, 2015, p. 39) and determines the framework for dissertation in practice. Herr and Anderson (2015) further defined positionality as a relationship between the researcher and participants. Positionality deeply influences the research and how the researcher conveys information as well as analyzes and interprets the data. During this research, I identified as an insider in collaboration with other insiders as I collaborated with other individuals within the school including the fifth-grade science
teachers and administration. This type of research can “have a greater impact on the setting, but also has the potential to be more democratic” (Herr & Anderson, 2015, p. 45). I am considered an insider as I centered this research within my own school and conducted the research on students with whom I interact. Outside of myself, the research included other stakeholders such as other science educators as well as administration, both at the school and district level. Other stakeholders are included in this research as it is viable to their practice and making informed decisions regarding both upper elementary and middle grades science education in the district as students take state-mandated, cumulative, standardized science tests in both fifth and eighth grade.

When I open my mouth to speak, I am clearly from the South. Inviting questions about my experiences and background. Given then thick drawl in my voice, some people are taken aback that I am educated. Identifying as multiracial, specifically White and Native American, I am judged and treated as a White woman due to my light eyes and complexion. As a product of a small, rural town, my personal public education experiences have allowed me to understand the unique challenges that impact these communities. I have experienced the lack of educational and exploratory opportunities available in comparison to more suburban and urban areas. My upbringing within the U.S. Bible Belt showcased stereotypical gender norms and roles within my community. Manufacturing jobs dominated my hometown and a high demand for educational opportunities did not exist.

Neither of my parents graduated high school and both later completed their GEDs while holding working-class jobs. My parents have always had high expectations—I was never once asked if I were going to pursue college, the question was: Where are you
going to college? As a first-generation college student majoring in biology at a major university with students from across the world, I had a firsthand realization of the differences for students from towns like mine compared to other areas. I realized place makes a difference: different opportunities, different expectations, and different stereotypes.

Professionally, I have taught upper-elementary mathematics and science in a rural community much like the one where I was raised. As an educator, I have direct knowledge of the plights facing public-school systems in rural communities. I carry strong beliefs about student abilities and class expectations, evident in my interactions with my students. I hold students to high expectations, without exception. My driven and curious nature propels me forward and drives me to continue to try to promote these characteristics in students; I want them to explore, to ask questions, and to determine creative and innovative ways to solve problems.

I am committed to bridging gaps that exist in rural education and ensuring that these students are afforded the opportunities that they deserve, while meeting their academic needs. As the mother of children—including a daughter—who attend rural community schools, I understand the importance of ensuring that all students can explore and access rich, engaging curricula that ignite a passion for learning within themselves.

**Research Design**

I conducted this study using action research as the problem warranted a change that would impact practitioners and students directly. Efron and Ravid (2013) defined action research as a type of inquiry conducted by a practitioner in a familiar setting to improve their professional practice and positively impact student learning. Saldaña
(2021) noted that action research brings about a constructive change in a setting. Action research is further defined as a “reflective practice” (Herr & Anderson, 2015, p. 3). Self-reflection is a necessary component of the teaching profession as it allows the practitioner to manage the demands and requirements of their position (Kaunisto et al., 2013). Research rooted in inquiry and exploration allows researchers to be immersed in the entirety of the process and effectively implement findings in their own classrooms and professional settings (Efron & Ravid, 2013). As the research assisted in promoting professional growth and self-improvement as an educator as well as allowed for reflection of best practices to understand student deficits, action research was the most appropriate method. The research also informed practical changes to improve science and engineering content understanding and self-efficacy in these areas.

To gather adequate qualitative and quantitative data, I used a mixed-methods approach. Mixed-method research “parallels everyday human problem solving in a way that neither qualitative nor quantitative methods alone can do” (Tashakkori & Teddlie, 2010, p. 273). Mixed-method research allows the “blending or combination of qualitative and quantitative research methods and techniques into a single study” (Efron & Ravid, 2013, p. 45).

Mixed methods accommodate various forms of data with the purpose of responding to the same research question (Efron & Ravid, 2013; Pickard & Childs, 2013). This research focused on the quantitative measure of academic achievement while analyzing both quantitative and qualitative measures of self-efficacy. Mixed-method research is flexible and can intertwine with action research (Ivankova, 2015; Plano Clark & Ivankova, 2016) as it provides a foundation to address “complex, practical problems”
(Ivankova & Wingo, 2018, p. 985). Research also suggests that mixed method research in conjunction with action research produces “rigorous and cohesive inferences” about the issues that are being investigated (Ivankova & Wingo, 2018, p. 979).

More specifically, I used a case study to examine the impact of the EDP on science and engineering student achievement and self-efficacy. Case studies aim to result “in new learning about real-world behavior and its meaning” (Yin, 2012, p. 4).

**Context and Participants**

The location for this study was a rural district within a mid-Atlantic state with a total student population of approximately 5,036 students ([State] Department of Education, 2021a). The district includes five elementary schools, two middle schools, and one high school. Fall 2022 enrollment data provided by the state Department of Education (2021a) showed an enrollment of 74 students in Grade 5 at The Point Elementary, while racial and ethnic data provided the following information for the group of students: 84% White, 4% Black or African American, less than 1% Asian, 2% Hispanic, and 10% Non-Hispanic, two or more races. Approximately 58% (n = 43) of the students identify as female ([State] Department of Education, 2021a). Research occurred in the students’ 5th grade science classroom. Whereas all classroom students completed the engineering design activities, I only collected individual participant data from female students. I invited all female students to participate in the research study; 39 of the 43 potential participants received parental permission. These participants were spread out across each of the four science courses. I selected three students from each class to participate in semi-structured interviews, resulting in 12 total interview participants.
Data Collection and Analysis

I gathered qualitative and quantitative data using an assortment of instruments that best reflected a mixed-methods approach as well as provided reliable and legitimate data. Practitioner research data should be “purposeful, deliberate, organized, and systematic” (Efron & Ravid, 2013, p. 85). Mixed-method techniques enable researchers to “expand the scope of, and deepen their insights, from their studies” (Sandelowski, 2000, p. 246). Combining both types of data allows numeric data to intersect with observations and narratives (Ivankova & Wingo, 2018).

Student Achievement

I used quantitative assessment data (Efron & Ravid, 2013) to measure student achievement, distributing a pre and post assessment to all participants to determine changes (Mertler, 2019). The assessment included questions derived from previously administered state released Standards of Learning assessments that focus on science and engineering practices; I used standards for Grades 4 and 5 as the test is cumulative. The assessment data were official artifacts (Efron & Ravid, 2013). I analyzed change in scores from pre to post assessment for statistical significance using a paired t-test. I also used formative student checkpoint assessments after the first two engineering design activities to measure achievement of specific content aligned to each design activity.

Science and Engineering Self-Efficacy

I measured science and engineering self-efficacy using the Student Attitudes Towards STEM (S-STEM) survey developed by the Friday Institute for Educational Innovation (2012). This survey measured attitudes toward STEM subject areas and interest in STEM careers. Students completed this scale using Google Forms, and I
analyzed information for each participant using descriptive and inferential statistics. The survey was completed at the onset and completion of the research.

I conducted semi-structured interviews with students, using questions I prepared in advance through the lens of constructionism, but that were open-ended and could give way to questions or conversations that were not preplanned (Efron & Ravid, 2013). This type of interview facilitates deeper, more meaningful conversations that are not constrained by a series of strict, matter-of-fact questions. Interviews allowed participants to provide detailed information about their experiences and allowed me to delve into information I could not directly observe (Creswell & Creswell, 2018). The interviews guided conversations about students’ beliefs and abilities regarding engineering practices and enabled me to understand how students feel about their ability to do science and engineering. Interview questions centered around student experiences with the EDP, including how students felt the process influenced their science and engineering self-efficacy.

Student responses gave way to new, unscripted questions regarding the EDP and student experiences. I analyzed and codified the transcripts to identify recurring themes or patterns that demonstrated “significant connections and relationships among the parts” (Efron & Ravid, 2013, p. 166), yielding accurate interpretation of the findings. Interviews were imperative to the research process, providing detailed responses (Mertler, 2019) and including student voices and formed opinions for more authentic and relatable data that truly reflects their thoughts and intentions (Danby, 2017; Hatzigianni et al., 2020; Moss & Clark, 2011).
Significance

As the purpose of this study was to improve my practice and directly relates to those affected by the problem, this research constituted action research (Efron & Ravid, 2013). The cyclical approach allowed for reflection, planning, action, and observation (Ivankova & Wingo, 2018). As action research is based on situations and specific circumstances, the findings are not absolute (Koshy, 2010). The findings are applicable to their context and are focused on bringing about real-time change and solutions through a deep-dive of the problem of practice. This research is rooted in a bottom-up approach that directly relates to involvement fueling changes, as opposed to a top-down approach that commonly occurs with an outsider making decisions that are not respective of the actual population (Law, 2007). My stance differed from that of an outsider who conducts generalized research (Efron & Ravid, 2013); thus, this study is not intended to be generalizable to outside environments. Action research is designed to benefit the practitioner’s particular student population and classroom as well as improve their teaching practices.

This research is significant as it relates directly to my practice and aims to improve the academic performance and self-efficacy of female students in science and engineering. These characteristics of students are attributes they will carry with them throughout their academic careers and improvement in these areas may spur interest in science areas and ultimately lead to success beyond the fifth-grade science classroom. Improving understanding of STEM standards will help in diversifying the student population interested in STEM careers and build upon 21st-century skills that are necessary for students to become productive members who are able to sustain society
(Austin, 2017). Application of these concepts across subject areas allows students to solve real-world problems and assist themselves in understanding the world around them, ultimately preparing students to be globally competitive promoting gender equity in STEM career fields (Madden et al., 2016).

Reflection from this research will allow me, as an educator, to make informed decisions that are supported by data. Critiquing my own lessons, learning units, and interactions with students will assist in developing curriculum that addresses learners’ needs and further improves their science and engineering academic performance. As an educator, I must be aware of the knowledge base that students have and provide rich and meaningful experiences that develop their skills (Isabelle & Zinn, 2017). The information gleaned from this research will allow me to improve my practice and better prepare students for my class and future STEM courses.

**Organization of the Dissertation**

This dissertation in practice is comprised of five total chapters. Chapter 1, the current chapter, introduces the problem of practice, rooted in rural communities’ inequitable access to educational resources. This chapter also establishes reasoning for the use of the EDP as a solution. Also included is a justification for choosing action research as well as the methods for the research design.

Chapter 2 provides a detailed literature review. The relevant literature focuses on rural, female students regarding science education and the impact of the EDP. I also explore the impact of self-efficacy on student performance and achievement. Other relevant research centered on rural female students in general and their use of hands-on
activities and the EDP, as much literature specific to this problem does not exist. This chapter also focuses on other gaps in existing research.

The third chapter focuses on the research design. I provide a detailed account of the context, setting, and participants. The chapter also expands on the methods of data collection and analysis.

Chapter 4 focuses on the research finding, homing in on data and results. The chapter includes comparisons of numerical student achievement data on pre- and post-assessments and checkpoint assessments. Scales to measure science and engineering self-efficacy surfaced trends and changes from the first administration to the second. This section also includes a detailed discussion of the findings from student interviews to include recurring themes or noticeable correlations.

The fifth and final chapter concludes the dissertation. I present detailed interpretations of the data from the previous chapter. In addition to conveying how the information can inform future action, I discuss overall implications of the findings.

**Glossary of Key Terms**

The following definitions and explanations clarify the operational use of key terms in the context of this research.

The standard definition of **creativity** exists as a component that “requires both originality and effectiveness” (Runco & Jaeger, 2012, p. 92) and refers to the ability for individuals to generate new concepts (De Bono, 1970). Creative thinking allows responding to problems by relying on knowledge, motivation, and emotions (Lucchiari et al., 2019; Vygotsky, 2004). Creativity is considered a 21st-century skill (Austin, 2017) and is measured in attributes of fluency, flexibility, elaboration and originality (Shively et
al., 2018). Scientific creativity depends on a relationship between scientific knowledge, processes and skills and creative problem-solving as well as both divergent and convergent thinking (Yang et al., 2016).

The **engineering design process**, commonly referred to as EDP, is a “flexible framework that organizes how inventors and engineers ask questions, build and test prototypes, seek solutions to problems, and communicate results” (Jackson et al., 2021, p. 26). Students follow this process to seek solutions to design problems.

When students partake in **inquiry-based learning**, they are using programs that are student-led and promote learning in an environment that is learner-centered (Blessinger & Carfora, 2015). Inquiry-based learning allows students to ask questions and explore the learning around them, providing opportunities for digging deeper into curriculum (Bailey, 2018).

By definition, a **makerspace** is a space that promotes hands-on activities and lessons that utilize various types of technologies (Keune & Peppler, 2019). Makerspaces include art, science, and engineering (Sheridan et al., 2014) and foster collaborative problem-solving (Kajamaa et al., 2020).

**Self-efficacy** is an individual’s belief in their ability to achieve a specific outcome (Bandura, 1986; Marra et al., 2009). Self-efficacy influences motivations, aspirations, and responses to difficult situations (Pajares & Urdan, 2006).

The **Standards of Learning Assessment** is a standardized assessment administered in reading, writing, mathematics, science, and history/social sciences that measures students’ performance against the state’s expectations for student achievement ([State] Department of Education, 2021c). Teachers review the test items intended to
measure students’ academic understanding at the end of each grade level ([State] Department of Education, 2021c).

**STEM** is used to describe the four elements of science, technology, engineering, or math in relation to stand-alone content areas. **Integrative STEM Education** refers to an integrative approach that uses “purposeful design and inquiry” (Sanders, 2009, p. 21). This type of “pedagogy purposefully combines technological design with scientific inquiry, engaging students or teams in scientific inquiry situated in the context of technological problem-solving” (Sanders, 2009, p. 21).
CHAPTER 2: LITERATURE REVIEW

As someone who has taught in various areas of the United States and across many grade levels, I observed that female students are often less engaged in science and engineering content than male students, and I also noticed a difference in rural communities versus suburban ones. Within my current district, male students outperformed female students in science academic areas on state standardized assessments in fifth and eighth grade. Moreover, female students approached difficult learning situations with the mentality that they were not capable of doing well. As a K-5 resource teacher, I experienced this phenomenon across multiple grade levels. I sought to create a learning environment that nurtured creative and rich learning experiences for students while building their content knowledge in both engineering and science academic areas as well as promoted positive beliefs about their abilities in these areas.

With the intent identified, I completed a detailed review of existing literature to develop two research questions:

1. How can use of the EDP improve fifth-grade rural female students’ achievement in science and engineering standards?

2. What is the effect of students’ use of the EDP on female students’ science and engineering self-efficacy?

This action research study implemented strategies that focused on developing a rich understanding of academic content through rural, female students’ applying the EDP.

This chapter serves as a thorough review of the literature surrounding science and
engineering education in rural communities, female representation in these two areas, and an exploration of the EDP in education. In addition to exploring literature on the impact of design-based learning environments, I also review the theoretical framework for this study and elaborate as to how the theories supported my intervention.

**Criteria for Reviewing Research**

I gathered research for this literature review primarily using Google Scholar and the University of South Carolina library databases. The common databases included Education Source, ERIC, Academic Search Complete, and Dissertations and Theses Global, which provided relevant information pertinent to the focus of the literature review. Science and STEM education journals were also a focus of research. An array of resources complemented the needs of the research and presented varying perspectives conducive to drawing overall conclusions.

Search terms included design process, collaborative learning environments, critical thinking in elementary classrooms, classroom makerspaces, female students and STEM, elementary science classrooms, engineering design process, engineering design process in elementary classrooms, engineering practices in elementary classrooms, and science and engineering practices in elementary classrooms. I used “elementary” to isolate research rooted in elementary school settings, but I also explored research without this identifier if it proved relevant.

Other criteria included focusing on research conducted in classrooms or settings within the United States; these studies were facilitated parallels between classroom preparation and workforce data within the same country. Some research did not meet this intended criterion but nevertheless offered valid findings related to my focus. All
resources except for dissertations were peer-reviewed. Critical review ensures work is valid, original, and actively contributes to a particular research area (Kelly et al., 2014). Dissertations provided rich and relevant information and have been closely monitored by academic scholars. All resources were originally written in English to avoid translation mistakes, and I only reviewed works to which I had the full access.

**Science and Engineering Education in Rural Communities**

The U.S. Bureau of Labor Statistics (2021) projects that STEM-related careers will grow by 8.0% by 2029. This projected growth indicates that an increased number of individuals will need to pursue STEM degrees to keep up with the professional demand. While approximately one in every five students attends a rural school (Showalter et al., 2019), rural students are underrepresented in STEM fields. Compared to their suburban peers, who represent approximately 16.6% of those enrolled in postsecondary STEM degree programs, rural students only account for 12.6% (Saw & Agger, 2021). The lack of rural students pursuing STEM degree programs reflects the plights facing rural students and school systems.

Rural students encounter many impediments throughout their educational careers that keep them from completing college. Hartman et al. (2017) cited “financial burden, a lack of nearby jobs that require a degree, geographic isolation from higher education institutions, reduced access to rigorous curricula in high school, and family and societal expectations to not attend college” (p. 140). Worsham et al. (2021) surveyed 12 rural high school graduates pursuing engineering degrees at land-grant institutions in the southern United States. Participants felt their decision to pursue engineering was not widely accepted by their peers and that their high school did not provide adequate STEM
learning opportunities including coursework, extracurriculars, engineering pathways, or advanced coursework for college credit. All participants agreed that school and community members played a “large role in informing them about engineering and guiding their college choices” (Worsham et al., 2021, p. 37).

Byun et al. (2017) further argued that student engagement in programs and activities that help prepare students for college are more predictive of their likelihood to attend a 4-year college than their aspirations. These findings indicate “the importance of rigorous academic curriculum and access to college planning resources in guiding rural youths’ transition to college” (Byun et al., 2017, p. 832). Comparing the achievement scores of third- through eighth-grade students nationwide yielded no significant difference between rural and nonrural students (Drescher et al., 2022); however, there was a significant difference in the percentage of rural students who attend and graduate college compared to their nonrural peers. These findings suggest academic achievement is not the primary factor associated with attending college.

A study in a Midwestern community found local employers had difficulty finding qualified candidates with computer-related degrees in their community, suggesting local individuals lacked access to computational skills to adequately prepare them to pursue such degrees (Nixon et al., 2021). Another study followed ninth graders for a period of 7 years to understand the difference in STEM pathway enrollment in regard to students’ geographic location (Saw & Agger, 2021). Rural high school students had fewer opportunities for advanced science and math courses including Advanced Placement Calculus, Statistics, Biology, Chemistry, and Physics. The study also showcased that rural schools were less likely to hold such events as science fairs, workshops, academic
competitions, contests, or after-school programs. While rural and suburban students had a similar interest in STEM careers at the onset of the study, 11.6% and 11.7%, respectively, a gap emerged by the end of the students 11th grade year. Research thus identifies a lack of STEM learning opportunities for rural students as a partial explanation for their lack of participation in STEM in upper grades and lower enrollment in postsecondary programs.

Utilizing available resources is one method for overcoming such barriers. Avery (2013) described the “Local Fisheries Project” in Maine, centered on high school students’ conducting interviews with local fishermen to make connections between ocean ecology and their community. While making such connections, the students were growing exponentially in their understanding of the state standards. The real-world experience of conducting interviews and working directly with a business that impacts the local economy provided an opportunity for students to realize the impact of such science concepts in their everyday lives. In California, a major agricultural employer partnered with area high schools by implementing an agriculture-based academy with math, science, and engineering pathways. The academy strengthened students’ proficiency in core areas so they could enter competitive post-secondary programs, that would provide them with the skills to work for the company after graduation (Hoffman & Cahill, 2016). Connection to local culture is paramount in rural communities and can lead to a greater understanding of STEM concepts as well as pursuance of such areas as a career (Harris & Hodges, 2018). Research also suggests most students choose an area of higher education that relates to their personal experiences and progress into with which they are familiar with or have had exposure to (Elam et al., 2012).
Rural schools struggle to “implement STEM instruction, often due to a combination of factors, such as location, resources, teachers trained for critical subject areas (like math and science) and the availability of professional development” (McKee, 2019, p. 116). Schools in rural areas frequently have difficulties with hiring and retaining highly-qualified, certified science and math teachers (Goodpaster et al., 2012). Rural communities’ remote locations, limited professional development opportunities, and lower salaries inhibit retention (Brownell et al., 2018), along with lower funding opportunities from rural governments (Monk, 2007). Rural schools often have lower enrollment numbers; therefore, teachers are often responsible for more than one core content area and are therefore unable to focus their expertise on a particular subject (Barley, 2018). The shortage of highly qualified educators has a direct, negative impact on STEM education initiatives. As Harris and Hodges (2018) argued “not affording equal STEM education opportunities to all students is reckless for a society that hopes to expand and regain its economic and intellectual foothold among other developed countries” (p. 3).

Science and Engineering Practices in Elementary Education

Research indicates STEM education is scarce in public elementary schools while engineering and technology education are almost non-existent (Hachey et al., 2021). Further research suggests lower elementary grades (i.e., K–2) dedicate extremely limited instructional time (i.e., less than 10%) to the teaching of science and engineering (Hachey et al., 2021; Pantoya et al., 2015). The most active use of engineering practices in public classrooms reflects the Next Generation Science Standards (NGSS; Thompson, 2017); however, not all states have adopted them. According to Thompson, teachers often
briefly touch upon the standards, rather than integrating them into the curriculum to adequately teach engineering practices.

The Framework for K–12 Science Education (National Research Council [NRC], 2012) and NGSS are the first standards in the United States to “explicitly include engineering” (Cunningham et al., 2020, p. 424). The framework centers “three major dimensions” (NRC, 2012, p. 1) that must be integrated into all aspects of public education to support learning in the classroom:

- Scientific and engineering practices
- Crosscutting concepts that unify the study of science and engineering through their common application across fields
- Core ideas in four disciplinary areas: physical sciences; life sciences; earth and space sciences; and engineering, technology, and applications of science (NRC, 2012, p. 1)

The NGSS integrates eight science and engineering practices set forth by the framework: (a) asking questions (for science) and defining problems (for engineering), (b) developing and using models, (c) planning and carrying out investigations, (d) analyzing and interpreting data, (e) using mathematics and computational thinking, (f) constructing explanations (for science) and designing solutions (for engineering), (g) engaging in argument from evidence, and (h) obtaining, evaluating, and communicating information (NGSS Lead States, 2013, p. 382).

Literature regarding engineering education denotes that a primary reason for a lack of sufficient engineering education in public school classrooms is a lack of teachers who are qualified, able, and willing to teach engineering (NRC, 2012). Preparatory
programs for elementary teachers often focus on mathematics and literacy education and lack formal training in science-based areas, including engineering. Hammack and Ivey’s (2019) research suggests teachers’ lack of knowledge may cause discomfort with and avoidance of teaching engineering concepts. Likewise, Cunningham et al. (2020) found teacher discourse and delivery of a design process unit led to different outcomes in student achievement. The study indicated a direct correlation between student understanding of science content and engineering pedagogy.

Porter et al. (2019) provided professional development in engineering education, and subsequent interviews with the participating educators suggested the training was helpful, but the participants worried those without such a resource would struggle to implement engineering practices in their classrooms. This was especially a concern for teachers hired after the school year had started or who were not offered such training but expected to implement such activities. The study also highlighted teachers’ conflation of project-based learning and engineering design as well as confusion regarding how and when to effectively implement engineering practices in day-to-day lessons and learning experiences. These findings further explain the lack of engineering education for young students—more about the barriers educators face than student ability or the complex nature of engineering.

Brophy et al. (2008) stated that “engineering education has an outstanding potential to increase conceptual understanding of STEM disciplines for all P-12 learners” (p. 370). Although the EDP is relatively new to elementary classrooms, research argues it can lead to increased academic achievement and positive attitudes toward STEM disciplines (Capobianco et al., 2018).
Design Process in Elementary Education

The EDP is rooted in the real-life process engineers use and allows students to apply this process in the classroom to solve real-life problems, thereby providing a real-life context for science and mathematics learning (Bozkurt Altan & Tan, 2021). The EDP is a problem-solving process and a means for student learning of math and science concepts (Kangas et al., 2013; Kelley et al., 2015). As state standards have began to implement engineering practices, the implementation of engineering design became a vehicle by which to meet those goals (Kelley et al., 2015). Elementary science courses have used design activities to help students develop models and improve understanding of science concepts (Brophy et al., 2008). Moreover, focusing curricula on engineering design enables students to connect science and engineering processes (Cunningham et al., 2020).

In an exploratory case study, Van Gompel (2019) investigated the impact of integrating a design thinking process into learning activities in a third-grade curriculum focused on Native Americans. The study implied the EDP can impact students’ knowledge of academic content standards by creating a physical representation of their learning. Research conducted using Engineering is Elementary units (Museum of Science, 2022) with elementary students found that adequately designed curriculum allowed students to build upon both science and engineering concepts as well as created an equitable learning experience (Cunningham et al., 2020).

Ehsan’s (2020) case study that measured the use of the EDP with autistic children found it allowed students to solve open-ended problems through broad utilization of various skills. Marulcu and Barnett (2016) found that curriculum taught via the EDP
promoted communication among students. Relevant conversations led to students’ exploring open-ended problems and making connections between content areas and academic thoughts, thus deepening understanding. A study of middle school students’ participation in a design-based learning unit indicated the instructional method can increase creativity and is more effective at developing creativity skills than traditional teaching methods (Bozkurt Altan & Tan, 2021).

Findings also indicate elementary students are capable of interacting in design process activities and forming complex ideas and understandings from such activities (Koul et al., 2018). Scarano’s (2021) work also supports this notion by indicating engineering design’s applicability at all grade levels, even with early learners, and that a key component of successful implementation is framing relevant problems that provide engaging learning opportunities. Research also suggests that integrating teaching and learning into engineering curriculum at the elementary level would benefit students by building 21st-century skills (Gruber-Hine, 2018).

As with any approach to engineering education, the curriculum must be well-planned and meet the needs of diverse learners. Regarding younger students, incorporating understandable problems and content is also vital to successful use of the EDP. Literature suggests elementary students may highly benefit from integrating literacy into STEM learning as they may not fully understand large scale social issues or struggle to relate to hypothetical situations (Montgomery & Madden, 2019). For example, Montgomery and Madden used picture books and novels to allow K–5 students to explore solutions to plot conflicts. Young students may be more likely to understand the conflict a character faces than a more complex and detailed global issue. A study of early
childhood learners concluded that children displayed both academic growth and positive attitudes toward the process of making after utilizing the EDP in a makerspace environment (Hatzigianni et al., 2020).

Engaging students in problem-solving highlights their vital role in the process. Engineering design, noted as an iterative process, provides meaningful learning that establishes foundations for other STEM disciplines (Jia et al., 2021). Lindquist et al. (2020) found that giving elementary students an “Inquiry Zone”, a large room for inquiry-based, design-centered activities, heightened their engagement in the content. The participation of students and ability to develop solutions to problems supports the belief that makerspaces can help students by promoting science and engineering practices. This research shows that even young students without engineering exposure can successfully interact in design activities.

Hachey et al. (2021) suggested using materials and creating are crucial components of engineering practice and that when tasked with solving a problem, students will follow the steps of the EDP. A study of elementary students found that when completing design activities, students used reflective decision-making to understand previous work on the problem, communicate and analyze information from all students involved, and work as a group to determine the next course of action for their design (Wendell et al., 2017). Teachers have also reported that when utilizing engineering concepts, students are able to work towards important goals and exhibit positive decision-making, collaboration, and problem-solving abilities (McCormick et al., 2014; Wendell et al., 2017).
Research with third-grade students concluded that maker technology and activities in engineering design increased both students’ academic motivation and self-efficacy (Jia et al., 2021). Self-efficacy is labeled as an intrinsic motivation, therefore interest and engagement in engineering education catalyzes such intrinsic factors (Jia et al., 2021). Students are more apt to succeed, especially with difficult endeavors, when they believe in their abilities to overcome such difficulties. When Zhou et al. (2017) tasked middle school students with designing a toy using specific criteria, they observed students’ increased understanding of the EDP and improved self-efficacy beliefs.

Literature also shows that educators believe that the engineering design process allows students to transform their relationship with failure (Maltese et al., 2018). Design environments encourage learners to actively participate in activities and are found to decrease student anxiety and fear in relation to their schoolwork (Honey & Kanter, 2013). Hatzigianni et al. (2020) found that students exhibited the perseverance to continue to solve problems even after encountering failures, while other research found that an understanding of failure further developed innovation and creativity (Maltese et al., 2018).

Ortega (2017) suggested positive attitudes and perceptions of STEM fields in elementary students signifies a high likelihood of positive interactions with STEM areas in future learning experiences. Thorough engagement in activities encourages students to take risks, reflect and evaluate their learning (Doubet, 2022). This positive perception extends across grade levels and into postsecondary education. A study in which undergraduate students explored the EDP by creating a wallet design for an intended user
exposed many to the process for the first time; participants noted that this exposure promoted consideration of careers in engineering (Steele et al., 2018).

Female Engagement in Science and Engineering Practices

Varma (2018) noted that demographics in science and engineering fields are not any more diverse than they were 10 years ago and that women make up only 29% of scientists and engineers. To narrow the gender gap in engineering, McLean et al. (2020) suggests educators must focus on helping young girls to identify with engineering, describing a study in which elementary students partnered with undergraduate engineering students to complete a design activity. The intervention encouraged student participation and helped build engineering identity. Female students were most impacted by personal bonds they formed, and both male and female students preferred to work toward a group goal opposed to competing with classmates. In another study, Wieselmann et al. (2021) observed three groups—male, female, and mixed-gender—as they explored an integrated STEM unit about light. The female students struggled more with the open-ended nature of design activities, and the researchers found students needed support in developing group norms. Further, they noted students likely needed added support in being able to effectively measure task completion and success.

In an inquiry- and design-based learning unit on sound that gathered data from fifth- and sixth-grade students, Slim et al. (2022) found a correlation between students’ attitudes toward engineering and gender, with males having a more positive attitude than females. A study by Barton et al. (2017) in which middle-school students made community-based engineering activities found that girls engaged heavily in activities that were relatable and indicative of real-life experiences.
Theoretical Framework Support for the Design Process

I explored related literature through the three theoretical lenses introduced in Chapter 1: constructivism, constructionism, and situated learning theory.

Constructivism

Using the EDP as a teaching methodology brings the constructivist theory to life (Scheer et al., 2012; Van Gompel, 2019). Harlow et al. (2006) argued that children learn by encountering, exploring, and attempting to develop new information. Analyzing the importance of children’s interactions within the environment is imperative; this includes both physical and mental interactions. Design thinking allows students to develop a presentation of their knowledge (Van Gompel, 2019).

Constructivism can “increase students’ understanding of complex systems as well as be more interesting, engaging, and motivating for students when assigned authentic problems studied within cooperative learning environments” (Kelley & Kellam, 2009, p. 40). McSpadden and Kelley (2012) used a constructivist approach to the EDP in a technology teacher education course. They allowed participants to identify a problem to solve and both male and female students applied their strengths and understandings of the world to develop a solution. In contrast, Arthurs and Kreager (2017) found that resistance to active learning practices was detrimental to students in college science classrooms. As Nadelson (2021) contended, “student-centered learning that can occur in makerspaces is conducive to supporting constructivism” (p. 105).

Constructionism

Constructionism is rooted in the idea of learning by doing (Ackermann, 2001; Morado et al., 2021; Papert, 1993). Psenka et al. (2017) noted that constructionism allows
learners to take control, placing the learning process directly with the learner. Ackermann (2001) argued that students’ expression of ideas and learning in situations is essential to the learning process. Lee and Hannafin (2016) argued, “students invest affectively in personally meaningful projects that involve design, development, and presentation of artifacts relevant for authentic audiences” (p. 712).

Creating objects, whether physical or virtual, allows students to understand abstract concepts and constructing objects can enhance overall opportunities for learning (Downey et al., 2022). The EDP allows students to create solutions to problems by melding their knowledge with specific criteria related to a design problem, producing a physical representation of their thoughts (Lee & Hannafin, 2016). Psenka et al. (2017) argued, “constructionism supports different ways of learning rather than restricting learning to the formal and impersonal learning imparted through verbal modes” (p. 9).

Constructionist classrooms and learning environments transform the role of the teacher. Facilitating the learning process as opposed to dictating it, teachers take a step back from traditional roles to allow students to learn through active engagement (Downey et al., 2022). Such learning environments also create a community of learners as students share their creations, provide feedback to their peers, and reflect on their own learning (Lee & Hannafin, 2016). This community of learners is vital to phases of the EDP in which students analyze and redesign their solutions as needed.

**Situated Learning Theory**

Sadler (2009) argued that within the context of situated learning, activities in which students partake must be positioned within the context to provide authenticity and that completing an activity for the sake of doing so is authentic. For example, Sadler
described a high school laboratory experiment based on a set of defined steps versus one that immerses students in a laboratory environment and may lead to other tasks. Situated learning theory suggests students who interact with and utilize their surroundings learn in a much more significant manner. Likewise, Stein (1998) argued that situated learning centers cooperative activities that allow students to physically interact within their learning environment and dive into critical thinking skills. In the word of Brown et al. (1989), “activity and situations are integral to cognition and learning” (p. 32).

Situated learning is further defined as a “theoretical perspective on the nature of knowing and learning” (Sadler, 2009, p. 2) that emphasizes the learning environment (Lave & Wegner, 1991). The learning environment comprises ideas, tools, and resources developed by the learner and other participants (Sadler, 2009). Knowing and learning are not “isolated events that occur in the minds of individuals” (Sadler, 2009, p. 2); rather, participation in an environment and engagement in a community fuel the processes of knowing and learning. Knowledge and concepts will continue to evolve with each new application opportunity (Brown et al., 1989). In a study with undergraduate nursing students, Kim et al. (2022) found that students who partook in role-playing exercises, received feedback, and had time for reflection learned effectively and were able to translate their knowledge into other scenarios.

Summary

Makerspace environments provide physical spaces and materials for students to develop tangible solutions to problems. Constructivism, constructionism, and situated learning theory provide an avenue for effective learning via the EDP in such environments by emphasizing active, hands-on creation; engagement of students in the
learning process; and personal meaning-making through authentic experiences. Situating the EDP in a makerspace environment serves as a practical application of constructivism as students actively engage within their learning environment and apply prior knowledge to develop new knowledge. Through the lens of constructionism, makerspace environments allow for the direct development of artifacts that create meaningful experiences for students (Hartzigianni et al., 2020). As the situated learning theory underscores that learning occurs when students have a direct involvement in the learning experience through relevant and authentic problem-solving, the EDP allows students to explore real-life problems that exist and develop potential solutions to such problems.

Engineering design in a makerspace environment provides a basis for the collaborative, problem-solving experiences that are vital to student success. Through this interactive environment, students are able to work alongside their peers to solve authentic problems. This immersive learning experience allows students to make connections between their surrounding world and the academic content they are learning, and allows the application of this knowledge to solve problems.

**Implications and Considerations**

Some students may struggle with change in their normal learning environment, and this disruption may lead to initial reluctance or unwillingness to participate (Jocius et al., 2020). Any introduction of a new learning environment and methods requires patience and procedural understanding that often comes with repeated use and exposure. Teachers should not dismiss this reluctance as disengagement or lack of interest; they must understand why a student is not interacting in the environment before drawing conclusions.
When utilizing makerspaces and the EDP in elementary classrooms, teachers must consider the misconceptions that may occur. Students must understand the difference between factual questions and those that are researchable (Hill-Cunningham et al., 2018). As many young students are beginning to develop analytical and critical thinking skills, their level of understanding must be considered. Research with young students shows that they often view the EDP as linear instead of cyclical (Hill-Cunningham et al., 2018). An important facet of engineering education is allowing students to revisit their solutions, improve, and reevaluate, so students must understand how these stages are linked together to provide a viable solution to a problem.

Arguments against the EDP and makerspace environments are often rooted in the diversion from standards-based learning or lack of focus on mandated standards (Falloon et al., 2020). The EDP provides ample opportunities to integrate standards from across content areas and create rigorous, relevant curriculum that can actively engage students. The notion that engineering concepts are already being taught without being identified, as Mann et al. (2011) found, may rebut the idea that adding engineering education is “something else” for teachers to teach. Teachers need training to understand the integration of engineering education—ideally not in isolation from other subjects. This includes an in-depth review and analysis of curriculum and not just an insertion of a design activity.

Moreover, teachers must be aware of their students' development and interactions within the learning environment. They must ensure activities are appropriate for students and provide problem-solving opportunities students can readily understand; if students
are tasked with developing a solution that includes constraints and requirements they do not fully grasp, a positive outcome from the use of the EDP is less likely.

**Conclusion**

Much of the historical data about educational opportunities does not focus on rural communities, and policymakers are often disconnected from the challenges rural communities face (Drescher et al., 2022). Research must center around the gap between such geographical locations and STEM education initiatives to tap into the potential that exists in these small, rural (and often forgotten) communities (Harris & Hodges, 2018). This study investigated the impact of the EDP on rural, fifth-grade female students’ science and engineering achievement and self-efficacy. This study may address current gaps in literature by focusing on rural, upper-elementary girls, a scarce demographic in scholarship related to the impact of the EDP.

Inquiry-based learning allows students to flourish as they follow the EDP and explore facets of engineering education, regardless of the age level. A considerable gap exists in literature between engineering design-based learning environments, including makerspaces, and elementary students as much of the research is situated in either secondary grades (i.e., 9–12) or undergraduate settings. Research also frequently involves a small group of students who are likely participating in an extracurricular activity; this is not representative of all students and alienates specific groups. Much research is also dedicated to utilizing the EDP in learning environments where students solely experience exploratory learning without much teacher guidance or involvement whereas elementary students—and those without any understanding of the EDP—require guidance and instruction to work through design challenges. Therefore, while design environments are
student-centered and inquiry-driven, teacher interaction and involvement are necessary as students navigate the space.
CHAPTER 3: METHODOLOGY

This action research study aimed to determine the effects of the use of the EDP on rural, fifth-grade, female students’ science and engineering academic achievement and self-efficacy. Evidence the EDP provides learning opportunities that increase STEM content knowledge, improves attitudes toward STEM, and increases student knowledge of STEM careers (Hirsch et al., 2017). As women continue to account for fewer STEM undergraduate degree holders (National Center for Education Statistics, 2021) and less than one third of the STEM workforce (National Science Board, 2018; Bahar et al., 2022), initiatives must focus on female students are a focus of initiatives to reach learners early in their academic careers. Science background, achievement, and attitudes influence students’ academic decisions and pursuance of STEM careers (Quinn & Cooc, 2015; Riegle-Crumb et al., 2012; Tai et al., 2006; Wang, 2013).

Despite efforts to enhance the prevalence of STEM education, young girls have continued to demonstrate a lack of interest and success in STEM disciplines (Kinskey, 2020). In addition to gender barriers, rural students also face a lack of STEM learning opportunities (Saw & Agger, 2021; Versypt & Versypt, 2013; Wheeler & Hall, 2021). Lack of access to formal and informal learning opportunities, including enrichment activities, clubs, and internships (Ihrig et al., 2022) decreases the likelihood of students’ successf in high school STEM courses. Outside of access to learning opportunities, rural female students commonly lack STEM role models (Wheeler & Hall, 2021), which contributes to decreased belief in their abilities.
This action research sought to close the achievement gap between male and female students in an upper-elementary, rural, mid-Atlantic classroom where standardized test scores showed a stark deficit in female scores compared to male scores. Two research questions supported the aim to improve the female students’ science and engineering academic achievement and self-efficacy:

1. How can use of the EDP improve fifth-grade, rural, female students’ achievement in science and engineering standards?

2. What is the effect of female students’ use of the EDP on their science and engineering self-efficacy?

This chapter explains the study’s methodological approach. This includes an explanation of action research as well as why it is the best avenue of research for this particular topic. Next, I discuss my positionality and role as a researcher. A detailed explanation of the setting and timeframe of the implementation of the research follows. After describing the participants, the chapter presents the research methods, including data collection instruments, procedures, and methods of analysis. This section provides a detailed explanation of these tools, including their validity and reliability, as well as a timeline for collecting data. To wrap up this chapter, I include a plan for reflecting with participants on data and a revised action plan.

**Action Research**

This study is situated in action research that is designed to bring about changes in the practices of those involved in the research with an emphasis on problem-solving. This cyclic process focuses on change (Denscombe 2007) and uses data to analyze and reflect
on practice. Specifically, I sought to collect and analyze data to bring about positive changes to practice in rural, fifth-grade science classrooms at my school.

I conducted the study to serve the immediate need of solving a recognized problem specific to my context; therefore qualifies as action research (Mertler, 2009). The overall goal of the research is to improve practice. My conclusions are intended to inform practices within the fifth-grade classrooms at my school, and I chose to implement the EDP to meet the needs of the learners in this specific context (Costello, 2011). Although others may find the data useful (Cain, 2011), both locally and in dealing with similar populations, my overall goal is to directly impact my practice and participants.

**Researcher Role**

I am an Instructional Technology Specialist at the research site. My primary role in the school setting is to assist teachers and students with the proper use of instructional technology and its implementation in curriculum to improve curriculum delivery, student engagement, and ultimately academic achievement. I maintained all other duties associated with my position in addition to conducting research. For this study, I collaborated with two Grade 5 science teachers to develop engineering design activities that correlated with classroom pacing. I also carried out the research, responsible for implementing and overseeing the use of the EDP, analyzing rubrics, conducting interviews, assessing students, and analyzing results.

**Research Site and Participants**

The Point Elementary is a P5 school in a rural community, situated in the coastal plain region of a mid-Atlantic state. The area borders a major river. Enrollment data from the 2022–2023 school year included a total of 455 students, including 74 fifth graders.
The student body was predominately White (79.1%). The races of the remainder of students are Hispanic (6.3%), Black (4.2%), Asian (1.5%), and Non-Hispanic two or more races (7.9%). Pacific Islanders and American Indians/Hawaiian Natives account for less than 0.4% of the total student population ([State] Department of Education, 2022). Fifth-grade students were representative of these racial groups: 84% White, 4% Black or African American, less than 1% Asian, 2% Hispanic, and 10% Non-Hispanic, two or more races (2021a).

Participants included fifth-grade girls and two science teachers at The Point Elementary. I selected both teachers based upon convenience and willingness to participate. Teacher A, a White woman, was in her third year of teaching at The Point and her first year of teaching fifth-grade science; she previously taught fourth-grade science and social studies. She was licensed in both elementary education and theatre with her self-proclaimed passion being the arts. Teacher B, also a White woman, was in her first year of teaching at The Point after spending 34 years working in both public and private education. Teacher B taught public middle school math, science, and social studies for 12 years and upper-elementary (i.e., Grade 4 and Grade 5) math, science, and social studies for 12 years in a parochial school. Other parochial experiences include 3 years as a librarian, serving as a science resource teacher for all elementary grades for 4 years, and 3 years of administrative experience. She was licensed in elementary education as well as middle grades math and science. Teacher data is showcased in Table 3.1.
I used purposive, representative sampling (Efron & Ravid, 2013) to choose student participants based upon specific criteria being fifth-grade, female students in the school. I identified 43 eligible students, but only selected 39 to participate in the pre and post assessments and surveys, due to a lack of parental permission for four students. Semi-structured interview participants represented a stratified, random sample (Creswell & Creswell, 2018), as I choose three female students from each classroom ($n = 12$) from the initial set of female students. The sample is representative of the fifth-grade female population at the research site as it includes 91% of all students in the target grade level. The sample population exhibits a wide range of abilities and understanding, indicative of a typical fifth-grade science classroom and encompasses the “actions, behaviors, and perceptions” (Efron & Ravid, 2013, p. 61) of such students.
The student participants represented four racial groups. The school district identified three as gifted and talented, one of whom I selected as an interview participant. Due to federal availability of funds and COVID-19 responses, all students received free lunch during the school year; therefore, household income was not a factor in the sample. Table 3.2 provides demographic information for both sets of students.

Table 3.2 Student Demographic Information

<table>
<thead>
<tr>
<th>Student Set</th>
<th>Race</th>
<th>Number of Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Students</td>
<td>White</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>Black</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Hispanic</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Asian</td>
<td>1</td>
</tr>
<tr>
<td>Interviewees</td>
<td>White</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Black</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Hispanic</td>
<td>1</td>
</tr>
</tbody>
</table>

**Informed Consent**

I obtained parental consent via a written letter sent home with all female students. The letter indicated the research purpose, intended goals, and tasks that students would be asked to complete. Of the 43 eligible students, one student’s guardian did not consent, and three other letters were never returned, even after two follow-up letters, a phone call, and an email.

Before inviting prospective participants, I sought Institutional Review Board (IRB) approval from the University of South Carolina (see Appendix H) and presented a written research proposal to the school board for approval. After receiving approval from both parties, I drafted and disseminated the invitation letter. I conducted the research
throughout the fourth quarter of the 2022–2023 school year, beginning in mid-April 2023, and ending early June 2023. As implementation of EDP into the science lessons allowed all students, regardless of gender, to actively engage with science and engineering curriculum while following the district pacing guide, I noted no ethical concerns.

EDP Intervention

Both science teacher participants assisted in the development of EDP activities that aligned with state standards in science and engineering (see Appendix A). Prior to this study, a 40-minute block of the day was reserved for either science or social studies instruction. Students received science instruction either 2 or 3 days per week, alternating with social studies. Only students identified as gifted and talented had any prior experience with the EDP as a component of their small-group instruction. For this study, the use of the EDP was integrated into the curriculum throughout a 6-week period. Students participated in the intervention during daily 40-minute science lessons.

At the onset of the study, I introduced students to the EDP in its entirety using an interactive presentation. The presentation provided visual representations of the process as well as an introduction to each step, including examples. Students also watched two videos: one that described engineers in kid-friendly language and a second that followed a group of similar-aged children through their use of the EDP to design an effective way to move groceries from one location to another using a bicycle. I also introduced students to the classroom makerspace environment, an area with an array of materials and tools students could use during their design activities.
The teachers and I developed each engineering design activity to aid students in understanding science and engineering standards as well as to facilitate connections to the world around them. The first activity, lasting 2 weeks, focused on physical science standards and tasked students with developing wheelchair prototypes that would allow an intended user to travel over three types of terrains following the Off-Road Wheel-Chair Challenge framework (Quinn et al., 2013). Students tested their models using a spring scale to pull the prototype across each of the simulated surfaces. This activity allowed students to explore assistive technology and understand the importance of providing an inclusive and accepting environment for all students as noted in the district mission statement. I administered the first checkpoint assessment after the completion of this design activity. This checkpoint accessed student understanding of Newton’s Laws with a focus on kinetic and potential energy and friction.

The second engineering design activity, implemented during Week 3 and carried out through the end of the fourth week, challenged students to develop a mechanism that would allow students to effectively clean a variety of trash and debris from a model of the ocean floor. Living in a coastal plain community approximately 40 miles from the Atlantic Ocean, students were familiar with the issues facing ocean ecosystems. From a local context, students experience pollution in both the rivers and major bay that border the county. At the completion of this design challenge, I administered the second checkpoint to assess student understanding of key characteristics of ocean environments.

The third and final engineering design challenge began in the fifth week of the study and ended mid-way through the sixth week. This challenge tasked students with developing a bridge that spanned a specific distance, testing their designs against others
in the class to determine which could support the most weight. The teachers and I intended this activity to help students understand the roles of civil engineers as well as engineering practices. Examples of student models appear in Appendix B.

Each design activity required students to complete an engineering design challenge handout they submitted to the teacher at the conclusion of the activity. Prior to constructing their planned designs, I introduced the engineering design challenge and allowed students to perform research to learn more about the problem and to help in developing realistic solutions. Students then brainstormed potential solutions to each design challenge and, after a collaborative effort, created a detailed drawing that included design notes or their intended solution. After the teacher verified completion of each of these steps, the students began building their designs. Upon completion of their first build, they tested the designs against the constraints and requirements of the challenge. Students had the opportunity to improve their designs as time permitted. Afterward, students reflected on their work and communicated their results via their handout. Table 3.3 provides a timeline for the data collection.
Table 3.3 Timeline of Data Collection

<table>
<thead>
<tr>
<th>Week</th>
<th>Tasks</th>
</tr>
</thead>
</table>
| 1    | Pre-Assessment  
      | Demographic Data  
      | S-STEM Initial Survey  
      | Begin Design Activity 1 |
| 2    | Complete Design Activity 1  
      | Checkpoint Assessment 1 |
| 3    | Initial Interview  
      | Begin Design Activity 2 |
| 4    | Complete Design Activity 2  
      | Checkpoint Assessment 2 |
| 5    | Begin Design Activity 3 |
| 6    | Complete Design Activity 3  
      | Post-Assessment  
      | S-STEM Post Survey  
      | Final Interview |

**Research Methods**

I chose mixed methods for a “broader, more credible understanding of the phenomena under investigation than a dichotomous qualitative/quantitative approach” (Tashakkori & Teddlie, 2010, p. 272), facilitating exploration of the outcomes of the intervention (Creswell & Creswell, 2018). This approach allowed in-depth exploration of how the EDP influenced both academic achievement and self-efficacy. Specifically, I conducted a convergent mixed-mixed methods case study (Creswell & Creswell, 2018) merging qualitative and quantitative data to develop a comprehensive analysis in response to the research questions. Such merging provides a foundation to answer multifaceted questions that may be difficult to answer using individual research methods.
(Tashakkori & Teddlie, 2010). Use of a case study allowed exploration of a specific, real-life situation (Simons, 2009) that led to a rich understanding of the impact of the EDP on both achievement and self-efficacy.

**Data Collection Instruments and Procedures**

In total, I used four instruments to gather data. Three instruments collected quantitative data: content pre and post assessments (Appendix C), content checkpoint assessments (Appendices D and E), and the Student Attitudes Towards STEM (S-STEM) survey (Appendix F). One instrument, a semi-structured interview protocol (Appendix G), yielded qualitative data. I also gathered demographic data at the onset beginning of the study.

**Content Pre and Post Assessments**

I gathered quantitative data using pre and post assessments for science and engineering achievement. My teacher collaborators and I developed the assessments using publicly released versions of previous standardized science assessments administered at the conclusion of fifth grade for students statewide. We chose questions correlated to the engineering design activities and science and engineering practices. Of the 25 total questions, 18 were multiple-choice with one correct answer, one required students to type a numeric answer, and one required students to select all four correct answers. The assessment was scored out of a total of 25 points, with one point awarded for each question. Students completed the pre assessment prior to their introduction to the EDP, on Day 1 of the study. They took the post assessment on the final day of the research, at the end of Week 6.
Content Checkpoints

Checkpoint assessments—brief formative assessments given twice during the study—yielded quantitative data. The first checkpoint was at the completion of the first engineering design activity, at the end of the second week. The second checkpoint was after the completion of the second design challenge, at the end of the fourth week. Although students completed three engineering design activities, the teachers and I administered the post assessment instead of a third checkpoint.

Each checkpoint consisted of five questions with a possible score of a total of 5 points (i.e., each question accounted for 20% of the checkpoint grade or one point). The questions derived from state-released assessments, as standardized assessments have been tested for validity and reliability and serve as reliable indicators of student learning (Greene et al., 2003). The teachers and I chose the questions based on their direct correlation to the standards explored within the EDP activity. Teacher-constructed tests may have higher content validity, yet they are less reliable than expert-created assessments (Efron & Ravid, 2013). Appendices C and D provide the two checkpoint assessments.

Science and Engineering Self-Efficacy

Quantitative measures of students’ science self-efficacy derived from the Student Attitudes Toward STEM (S-STEM) survey developed by the Friday Institute for Educational Innovation (2012). The Friday Institute developed two surveys: one measuring fourth- and fifth-grade attitudes toward STEM and interest in STEM careers, and another for Grade 6–12; I used the version for younger students, consistent with the participants’ ages (Unfried et al., 2015). This instrument measured students’ attitudes in
mathematics, science, engineering, technology, and 21st-century learning (Friday Institute, 2012). The survey also measured student career interest in various STEM fields that included physics, biology or zoology, medicine, and engineering. I did not measure students’ mathematics attitudes, which were beyond the scope of this study.

The S-STEM instrument was reliable and valid as determined by exploratory factor analysis and subject matter experts in prior studies (Friday Institute, 2012; Unfried et al., 2015). Feedback on the first version of the instrument informed revision (Unfried et al., 2015). The parallel version of the original S-STEM survey in Appendix F was developed for younger students; teachers for each respective grade level analyzed and reviewed the survey for appropriate length and difficulty. I used the younger student scale with permission and administered it twice during the study via a digital version in Google Forms. Students initially completed the survey during Week 1, the day after the completing the content pre-assessment and before their introduction to the EDP. They completed the survey for the second time after the third engineering design activity and post assessment in Week 6 as noted in the timeline, Table 3.3.

**Qualitative Interviews**

I gathered qualitative measures of engineering and science self-efficacy through semi-structured interviews. The questions were researcher-created (Appendix G) using Bandura’s (1977) four sources of self-efficacy, allowing students to relate their experiences with science and engineering, their comparison to their peers, influential experiences, and affective states. I prepared the questions prior to the interviews, but due to the nature of semi-structured interviews, students could “co-construct the narrative” (Efron & Ravid, 2013, p. 98) by bringing up issues of their own choosing.
Digging into students’ experiences spawned new ideas or findings that standardized questions would not have contained. I phrased questions in a manner to elicit “participants’ perceptions, knowledge, opinions, experiences, and beliefs with regard to the research topic” (Efron & Ravid, 2013, p. 101). Eliciting participants’ opinions and views of the EDP was vital to understanding the impact of the process on their self-efficacy. As shown in the research timeline, Table 3.3, I conducted interviews at the halfway point, during Week 3, as well as at the conclusion of the study in Week 6.

Three students from each of the four science courses participated in the interviews. I chose them randomly from the 39 participants given that purposeful, random sampling increased credibility (Palinkas et al., 2015). Each interview lasted approximately 15 minutes and occurred either in the courtyard of the school or the media center, away from outside distractions and one-on-one with the interviewee. I recorded responses via Google Docs during each interview.

**Pre–Post Assessments and Checkpoint Data Analysis**

I analyzed data from the pre and post assessments and checkpoint assessments using parametric tests in IBM SPSS Statistics (Version 29), due to the sample size \( n = 39 \) and the normal distribution of the data (Grech & Calleja, 2018). I compared differences in female students’ assessment data across time periods using a paired \( t \)-test. These results indicated the effect of the EDP intervention on achievement. I measured effect size using a Cohen’s \( d \) measure of sample size effect. I used a paired \( t \)-test to compare checkpoint assessment scores from the first checkpoint to the second to determine the impact of different design activities on the learning of specific content.
standards. For the checkpoint assessments, I also used a Cohen’s $d$ measure of sample effect size. The results appear in Chapter 4.

**S-STEM Data Analysis**

I analyzed quantitative data from the pre and post S-STEM survey using non-parametric tests in IBM SPSS Statistics (Version 29). As the survey used a Likert scale and provided ordinal data, non-parametric tests were appropriate. I compared results from each administration using a Wilcoxon signed-rank test, a non-parametric inferential statistical test, to determine statistical significance. I conducted multiple separate Wilcoxon signed-rank tests to determine statistical significance on individual areas of the S-STEM survey and measured effect size for each area of the survey. These results indicated the impact of the EDP on science and engineering self-efficacy as presented in Chapter 4.

**Interview Data Analysis**

I uploaded all interview responses—qualitative data collected through two rounds of student interviews—into QSR International’s NVivo 14, a common software program for qualitative and mixed-methods research. Digital coding yielded a robust, organized presentation of the data, which I analyzed deductively and inductively. I developed a priori codes prior to the onset of the study through analysis of the second research question, relying on Bandura’s (1997) four sources of self-efficacy: mastery experiences, vicarious experiences, verbal persuasion, and physiological states (see Table 3.4).
Table 3.4 A Priori Codes for Research Question 2

<table>
<thead>
<tr>
<th>Code</th>
<th>Definition</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mastery Experiences</td>
<td>Student interpretation of performance as successes or failures.</td>
<td>Statements that show students are influenced by personal successes and failures including personal accomplishments, learning from failure, task mastery, and the ability to teach others.</td>
</tr>
<tr>
<td>Vicarious Experiences</td>
<td>Student belief of self-abilities through observation of others.</td>
<td>Statements show that students are impacted by role models, modeling by others, comparison of self to others, peer-influence and collaborative learning environments.</td>
</tr>
<tr>
<td>Verbal Persuasion</td>
<td>Student is convinced by others of their own personal capabilities.</td>
<td>Statements provide the impact of positive feedback, constructive criticism, encouragement, and reassurance.</td>
</tr>
<tr>
<td>Physiological States</td>
<td>Physical and emotional reactions that impact perceptions of abilities.</td>
<td>Statements indicate positive and negative physical and emotional reactions including anxiety, self-doubt, stress, confidence, and excitement.</td>
</tr>
</tbody>
</table>

Note: Based on Bandura, 1977.

Interview questions, developed using the four sources of self-efficacy, elicited students' feelings about their ability to succeed in science and engineering. After a priori coding, inductive codes emerged from student responses (Miles et al., 2014). I open-coded responses before using pattern coding to group the coded data into themes (Miles et al., 2014). The emergence of these themes allowed a greater understanding of student
science and engineering self-efficacy, as well as how the EDP contributed to these feelings via direct quotes from participants.

During the manual coding of the responses, I wrote memos to assist in defining emerging themes from the data as well as noting interviewees’ perceptions and understandings. Memos provided reflective narratives that allowed further analysis of the data (Miles et al., 2014) and helped to identify inductive codes. Analyzing memos against interview responses and survey responses allowed triangulation of the data and improved reliability of the findings (Creswell & Creswell, 2018). Coding and analytic memo writing occurred simultaneously (Saldaña, 2021).

Table 3.5 provides an overview of the research questions, data sources and analysis methods.

### Table 3.5 Alignment of Research Questions, Data Sources, and Analysis Methods

<table>
<thead>
<tr>
<th>Research Question</th>
<th>Data Collection Techniques</th>
<th>Data Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>How can use of the EDP improve fifth-grade, rural, female students’ achievement in science and engineering standards?</td>
<td>Quantitative:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Demographics</td>
<td>• Descriptive Statistics</td>
</tr>
<tr>
<td></td>
<td>• Pre–post assessment</td>
<td>• Descriptive Statistics</td>
</tr>
<tr>
<td></td>
<td>• Checkpoint Assessment</td>
<td>• Paired ( t )-test</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Cohen’s ( d )</td>
</tr>
<tr>
<td>What is the effect of female students’ use of the engineering design process on their science and engineering self-efficacy?</td>
<td>Quantitative: S-STEM</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Qualitative: Interview</td>
<td>• Descriptive statistics</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1. Wilcoxon signed-rank test</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Inductive and deductive coding</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Pattern coding</td>
</tr>
</tbody>
</table>
Reflecting with Participants and Further Action

I conducted member checks with participants to ensure the qualitative data “present the participants’ perspectives honestly and accurately” (Efron & Ravid, 2013, p. 71). Specifically, I discussed the interview transcripts and my general conclusions with the respective student participants check for validity and ensure an accurate representation of each student’s feelings. The day after each interview, each participant was able to review their transcript and ensure it was representative of their intended answers. There were no discrepancies within the data.

This action research illuminated the needs of rural, fifth-grade, female students. The results may be transferable to other schools in the district, female students consistently score below male students on standardized science assessments across the rural district. Regardless of broader transferability, the results in Chapter 4 provide a basis for effective science instruction at The Point Elementary.
CHAPTER 4: DATA AND RESULTS

This mixed-methods action research study aimed to determine the effect of the implementation of the EDP on fifth-grade, rural, female students. The research explored two primary areas: academic achievement and self-efficacy in science and engineering.

Two research questions guided this study:

1. How can use of the EDP improve fifth-grade, rural, female students’ achievement in science and engineering standards?

2. What is the effect of female students’ use of the EDP on their science and engineering self-efficacy?

This chapter presents the findings, including quantitative and qualitative data. The first section presents quantitative results gathered from three data sources: (a) a pre and post assessment given at the onset and conclusion of the study, (b) checkpoint assessments given after the first and second design activity, and (c) a pre and post S-STEM survey administered prior to and after intervening. The second section presents qualitative data from semi-structured individual interviews conducted midway through and at the end of the study. These interviews yielded insight into students’ perceptions of their abilities in science and engineering. The final section of this chapter addresses each of the research questions against the collected data.
Quantitative Findings

I gathered all quantitative data through Google Forms. Each link tracked students’ email addresses for accurate identification and comparison of results. Student responses were also limited to one submission for all forms to avoid duplicate responses.

Science and Engineering Content Assessment

The teacher and I designed a pre–post assessment to determine science and engineering content achievement through performance (see Appendix C). As indicated in Chapter 3, we used questions from the State Department of Education’s Standards of Learning assessments. Participants completed the assessment during Week 1 and again in Week 6. The maximum score on the 25-question assessment was 25 points. We did not award partial credit Item 1; students had to provide all correct answers to receive a point. For Item 18, we only expected a numeric response, but accepted as correct any responses with a relevant metric unit of mass (i.e., gram) alongside the correct number.

To examine the quantitative data to determine if a statistically significant variation was present between each administration of the assessment, I used a paired $t$-test. After determining the data met the assumptions of normality, I calculated descriptive statistics and performed a paired $t$-test using IBM SPSS Statistics (Version 29). Table 4.1 reports the pre and post results, including the mean, standard deviation, paired $t$-test results, and effect size.
Table 4.1 Descriptive Statistics for Pre- and Post-Assessment

<table>
<thead>
<tr>
<th>Variable</th>
<th>Pre-test</th>
<th>Post-test</th>
<th>Paired t-test</th>
<th>Effect Size</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Assessment</td>
<td>14.79</td>
<td>1.33</td>
<td>18.67</td>
<td>1.14</td>
</tr>
</tbody>
</table>

**p < .01.

Results indicated implementing the EDP in the classroom positively impacted student achievement for the science and engineering standards. The pre intervention mean score was 14.79, while the post intervention mean score was 18.67. The p-value of .009 indicates the results are statistically significant. The effect size, calculated at 0.44 using a Cohen’s $d$, indicates a moderate relationship between the matched pairs (Sullivan & Feinn, 2012). I completed a one-way analysis of variance test to determine if any link existed between female students of various racial groups and post intervention scores. I noted no difference, calculating the $p$-value as 0.873. I performed no ad hoc tests for the post assessment, given Asian and Hispanic categories with fewer than two cases.

**Checkpoint Assessments**

As noted in Chapter 3, the teachers and I developed two checkpoint assessments using questions from state-released standardized assessments focused on the science and engineering standards related to each design activity, with the first being physical science and the second relating to earth and space systems. Students completed each five-question assessment after the respective activity. Each question was worth one point, with a possible range from zero to five. The first checkpoint consisted of five questions, four being multiple-choice and one requiring students to select multiple correct answers with no partial credit. The second checkpoint consisted of five multiple-choice questions.

Table 4.2 presents a comparison between the first and second checkpoint.
Table 4.2 Descriptive Statistics for Checkpoint Assessments

<table>
<thead>
<tr>
<th>Variable</th>
<th>Checkpoint 1</th>
<th>Checkpoint 2</th>
<th>Paired t-test</th>
<th>Effect Size</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean  SD</td>
<td>Mean  SD</td>
<td>p</td>
<td>d</td>
</tr>
<tr>
<td>Checkpoint</td>
<td>2.82  4.243</td>
<td>3.41  3.989</td>
<td>&lt;0.001***</td>
<td>1.05</td>
</tr>
</tbody>
</table>

***p < .001.

Comparing the data using a paired t-test, I calculated differences between the two checkpoint assessments as statistically significant (p < .001). Scores for students increased throughout the duration of the study with means increasing from 2.82 to 3.41. The effect size of 1.05, calculated using Cohen’s d, shows a strong relationship between the data.

**S-STEM Survey**

Participants completed an abridged version of the S-STEM Survey (Appendix F). Developed by the Friday Institute of Educational Innovation (2012), the survey, consisted of six areas to measure student attitudes toward science, engineering and technology, and 21st-century skills. The survey also measured student career interest in various STEM fields, predictions about their final grades in three subject areas, and personal knowledge of adults who worked in STEM fields.

Students completed the survey using a Google Form divided into six sections to correlate with each of the six subscales. Participants ranked their level of agreement with each statement. To scale these answers, I assigned point values ranging from 1 to 5 as follows: 1 = Strongly Disagree, 2 = Disagree, 3 = Neither Agree nor Disagree, 4 = Agree, and 5 = Strongly Agree. I reverse-coded Item 16, which is negatively worded. I also coded students’ career interest using a point value system in which 1 = Not at All Interested, 2 = Not So Interested, 3 = Interested, and 4 = Very Interested. The survey
asked students to predict how well they thought they would perform in areas of English, math, and science. Students rated themselves as “Not Very Well, which I valued as 1, “OK/Pretty Well” which I assigned a value of 2, and “Very Well” which received a value of 3. The last portion of the survey asked students if they knew any adults who worked in particular STEM fields. Responses of “No” received a value of 1, followed by “I’m Not Sure” = 2, and “Yes” = 3.

Each subscale of the survey included a different number of questions, so total points for each section varied. Attitudes toward science included 8 items with a maximum score of 40 points. Attitudes toward technology and engineering included 9 items, with a maximum score of 45 points. With 11 questions, the attitudes of 21st-century learning section had a maximum score of 55 points. Student STEM career interest allowed students to rank their interest in 12 areas, ranging from point values of 1–4, eliciting a maximum score of 48 points. Students could score a maximum of 9 points when predicting their academic grades in three subjects. For the final subscale of the survey, students could score a maximum of 12 points if they indicated they knew adults who worked in each of the STEM fields.

I administered the survey twice: at the beginning of Week 1, prior to any introduction or use of the EDP, and as the final data collection tool at the conclusion of the research. For each administration of the survey, I measured individual subscales by adding the total for each subscale. I calculated the student total score for the S-STEM survey by determining the total, raw-data score from each subscale. I then analyzed scores using a Wilcoxon signed-rank test, given the ordinarl data did not meet normal distribution assumptions. In addition to descriptive statistics, I determined effect size for
each subscale using IBM SPSS Statistics (Version 29) software. Table 4.3 provides results from both administrations of the survey.

Table 4.3 Descriptive Statistics for S-STEM Survey

<table>
<thead>
<tr>
<th>Variable</th>
<th>Median Pre-test</th>
<th>Mean Pre-test</th>
<th>SD Pre-test</th>
<th>Median Post-test</th>
<th>Mean Post-test</th>
<th>SD Post-test</th>
<th>Z</th>
<th>p</th>
<th>ES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Score</td>
<td>147.00</td>
<td>147.59</td>
<td>25.25</td>
<td>155.00</td>
<td>155.77</td>
<td>21.23</td>
<td>-2.57</td>
<td>0.010**</td>
<td>0.29</td>
</tr>
<tr>
<td>S-STEM Subscale</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Science Attitudes</td>
<td>30.00</td>
<td>29.67</td>
<td>7.06</td>
<td>33.00</td>
<td>32.62</td>
<td>6.21</td>
<td>-3.53</td>
<td>&lt;0.001***</td>
<td>0.40</td>
</tr>
<tr>
<td>Engineering/Technology Attitudes</td>
<td>32.00</td>
<td>31.28</td>
<td>7.88</td>
<td>31.00</td>
<td>32.44</td>
<td>7.62</td>
<td>-1.38</td>
<td>0.165</td>
<td>0.16</td>
</tr>
<tr>
<td>21st-Century Skills Attitudes</td>
<td>45.00</td>
<td>44.57</td>
<td>6.98</td>
<td>47.00</td>
<td>46.59</td>
<td>6.91</td>
<td>-2.60</td>
<td>0.009**</td>
<td>0.30</td>
</tr>
<tr>
<td>STEM Career Interest</td>
<td>27.00</td>
<td>27.21</td>
<td>7.31</td>
<td>28.00</td>
<td>28.08</td>
<td>6.21</td>
<td>-0.65</td>
<td>0.518</td>
<td>0.07</td>
</tr>
<tr>
<td>Anticipated Grades</td>
<td>7.00</td>
<td>7.03</td>
<td>1.31</td>
<td>7.00</td>
<td>7.31</td>
<td>1.13</td>
<td>-1.79</td>
<td>0.074</td>
<td>0.20</td>
</tr>
<tr>
<td>Adults in STEM Fields</td>
<td>8.00</td>
<td>8.08</td>
<td>2.14</td>
<td>9.00</td>
<td>2.27</td>
<td>2.27</td>
<td>-1.58</td>
<td>0.115</td>
<td>0.18</td>
</tr>
</tbody>
</table>

**p < .01. ***p < .001.

Results from the pre and post survey indicate statistical significance as the overall p-value is 0.010, which is less than the 0.05 benchmark value. Between the first and second administration of the survey, the median increased for all subscales except for attitudes toward engineering and technology. Statistically significant changes were only evident for science attitudes and 21st-century attitudes. The median score for the attitudes toward science subscale increased from 30.0 to 33.0 with a p-value of <.001, indicating statistical significance. Student 21st-century skills increased from 45.0 to 47.0 with a p-value of 0.009, also indicating statistical significance.

Students’ attitudes toward engineering and technology decreased from a median score of 32.0 to 31.0; however, these results are not considered statistically significant as
the $p$-value was 0.165. Upon review of the individual questions under the engineering attitudes subsection, I concluded that the two lowest-scoring questions both related to potential careers. The two statements were: (a) Designing products or structures will be important for my future work (median score of 3.0) and (b) I believe I can be successful in a career in engineering (median score of 3.0).

There was no statistically significant change associated with STEM career interest; however, a Spearman’s rho test confirmed a relationship between overall self-efficacy and student career interest. Overall scores on the S-STEM survey and career interest had a direct correlation with a $p$-value of $<0.001$, indicating statistical significance. There was also no significant change for students’ prediction of their grades or assertion of their knowledge of adults who worked in particular STEM fields. I used a Kruskal-Wallis test to determine if a relationship existed between student race and overall self-efficacy in science and engineering. I found no such relationship, given the $p$-value of 0.511.

**Qualitative Findings**

As indicated earlier, each of the 12 interview participants completed two semi-structured interviews—one mid-way through the study and one at the completion of the study, yielding a total of 24 transcripts.

**Deductive and Inductive Coding**

As noted in Chapter 3, Table 3.4, prior to the EDP intervention, I developed a list of four a priori codes through analysis of self-efficacy literature. I transcribed interviews as Microsoft Word files that I printed and read through independently. During this first read, I documented immediate thoughts and themes. These memos served as notes to self
(Saldaña, 2021). During this first cycle of coding, I only searched for evidence of the original four codes. At the conclusion of this initial analysis, each original code remained.

I uploaded the transcripts into QSR International’s NVivo 14 coding software for a subsequent round of coding. During this second read, I sought new inductive codes through open-coding (Miles et al., 2014). This process included information regarding students’ self-efficacy and perceptions of science and engineering that did not fit into the pre-determined codes. If a student statement—a sentence or partial sentence—warranted more than one code, I applied however many codes were applicable. During this round, nine different codes emerged. They appear in Table 4.4.
Table 4.4 Inductive Codes for Research Question 2

<table>
<thead>
<tr>
<th>Code</th>
<th>Definition</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engineer Mimicry</td>
<td>Student feels like an engineer or relate to engineers.</td>
<td>Statements show students perceptions of mimicking an engineer and how this influences their perceptions of self.</td>
</tr>
<tr>
<td>Influence of Abilities</td>
<td>Student indicates the EDP influenced the way they learned.</td>
<td>Statements show students believed the EDP changed the way they were able to learn science and engineering content.</td>
</tr>
<tr>
<td>Importance of Science and Engineering</td>
<td>Indication of the importance of science and engineering to society.</td>
<td>Statements indicate students believe science and engineering are both important in everyday life.</td>
</tr>
<tr>
<td>Career Aspirations</td>
<td>Interest in pursuing a career in a science or engineering field.</td>
<td>Statements demonstrate student interest in pursuing careers in science and/or engineering fields.</td>
</tr>
<tr>
<td>Creativity</td>
<td>Generating possibilities to solve a problem.</td>
<td>Statements support that the EDP allowed students to be creative in their problem-solving abilities.</td>
</tr>
<tr>
<td>Learning Shift</td>
<td>A change in the way students learn science and engineering.</td>
<td>Statements show student perceptions of changes to the way they learn science and engineering.</td>
</tr>
<tr>
<td>Hands-on Learning</td>
<td>Experiential learning that occurs through the immersion in an experience.</td>
<td>Statements indicate the impact of experiential learning on student perceptions.</td>
</tr>
<tr>
<td>Collaborative Learning</td>
<td>Working with peers to reach a common goal.</td>
<td>Statements indicate a collaborative working environment influenced student perceptions.</td>
</tr>
<tr>
<td>Authenticity</td>
<td>Genuine or real problem-solving experiences.</td>
<td>Statements indicate a link to real-world situations and connections.</td>
</tr>
</tbody>
</table>
Using QSR International’s NVivo 14, I calculated a percent occurrence for each code. This information is summarized in Table 4.5.

Table 4.5 Summary of Percentage of Deductive and Inductive Codes using NVivo

<table>
<thead>
<tr>
<th>Deductive Codes</th>
<th>Inductive Codes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physiological States (28.5%)</td>
<td>Collaborative Learning (10.0%)</td>
</tr>
<tr>
<td>Mastery Experience (17.3%)</td>
<td>Importance of S/E (8.4%)</td>
</tr>
<tr>
<td>Vicarious Experiences (3.2%)</td>
<td>Career Aspirations (7.8%)</td>
</tr>
<tr>
<td>Verbal Persuasion (1.6%)</td>
<td>Influence of Abilities (6.4%)</td>
</tr>
<tr>
<td></td>
<td>Learning Shift (4.0%)</td>
</tr>
<tr>
<td></td>
<td>Hands on Learning (4.0%)</td>
</tr>
<tr>
<td></td>
<td>Creativity (3.2%)</td>
</tr>
<tr>
<td></td>
<td>Authenticity (2.8%)</td>
</tr>
<tr>
<td></td>
<td>Engineer Mimicry (2.8%)</td>
</tr>
</tbody>
</table>

Emergent Themes from Qualitative Data

Analysis of the student interviews gave way to a collection of codes that powered the development of themes against the second research question. A theme is an “outcome of coding” (Saldaña, 2021, p. 19), and I used pattern coding to identify themes by summarizing data and grouping codes into themes (Miles et al., 2014). Four primary themes emerged from this analysis: positive attitudes toward science and engineering, the positive impact of the EDP, influence of affective states, and the transformation of student learning preferences.

Each theme demonstrates an overall positive impact on science and engineering self-efficacy. Positive attitudes towards science and engineering were supported by
mastery experiences and students noting the importance of science and engineering. The overall positive impact of the EDP was demonstrated through engineering mimicry, authenticity, creativity, influence of abilities, and career aspirations. Affective states influenced science and engineering attitudes. Positive affective states made an impact on students’ self-efficacy with many students noting pride and confidence in their science and engineering abilities. Negative affective state also influenced students’ attitudes with students demonstrating self-doubt as well as referencing anxiety, anger, and stress. The EDP transformed students’ learning preference through collaboration, vicarious experiences, hands-on learning, and verbal persuasion. Table 4.6 provides an overview of the developed themes, claims for each, and codes that align with this theme.

Table 4.6 Theme Emergence: Claims and Codes

<table>
<thead>
<tr>
<th>Theme</th>
<th>Claims</th>
<th>Codes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive attitudes toward science and engineering.</td>
<td>Responses noted a positive attitude toward science and engineering.</td>
<td>Mastery Experiences, Importance of S/E, Collaborative Learning</td>
</tr>
<tr>
<td>Positive impact of the EDP.</td>
<td>Responses indicated the EDP influenced a positive change.</td>
<td>Engineer Mimicry, Authenticity, Creativity, Influence of Abilities, Career Aspirations</td>
</tr>
<tr>
<td>Influence of affective states.</td>
<td>Responses indicated the EDP influenced emotional states.</td>
<td>Physiological States</td>
</tr>
<tr>
<td>Transformation of student learning preferences.</td>
<td>Responses noted a preference in the way students learn science and engineering.</td>
<td>Learning Shift, Hands-on Learning, Vicarious Experiences, Verbal Persuasion</td>
</tr>
</tbody>
</table>

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**Attitudes Toward Science and Engineering**

Students generally expressed positive attitudes towards science and engineering across both interviews. Students found science and engineering “interesting” (Student A, Student C) and “fun” (Student B, Student I). Student H felt “excited” when learning science. Two students expressed that while they liked science, they did not feel good at it; Student G blamed this on poor grades while Student F merely exhibited self-doubt.

Mastery experiences and high academic performance contributed to students’ positive attitudes in these areas. For example:

- I think that I’m good at science, I have good grades in it. (Student B)
- Science is where I have the highest grade. It is the only fun thing about school that I like. It is exciting when we get to learn new things in science. (Student A)

When asked if science and engineering are important, all students answered affirmatively. Some students measured the importance by noting the contributions of science and engineering to society:

- Yes, I think [science and engineering] are important because without science and engineering, I don’t know things like buildings or vaccines could be made. (Student A)
- Yes. Engineering and science help us to build and create things. A lot of things wouldn’t exist without these. (Student I)
- Yeah because there are jobs that involve it in everyday life so it’s very important and it helps to solve world problems. (Student D)
Science and engineering are important because in engineering you can make new stuff to help people and in science you can learn about theories and try to explain things. (Student C)

Students linked positive attitudes to mastery experiences and successful performance in areas of science and engineering. In addition to this belief, students also validated the importance of science and engineering in everyday life.

**Positive Impact of the EDP**

Students highlighted how the EDP aided in their overall understanding of science and engineering concepts. Students also drew connections between the engineering design activities and the real-world, developing authentic experiences. This theme was evident in responses such as:

- The engineering design process helped me by letting me solve a problem that I understood. It also helped me by letting me work with others and they helped me learn new things. (Student G)

- The EDP helped me to understand what I was learning about because we were able to try to solve a problem and solving the problem made what we were learning about seem real. (Student A)

Students’ self-comparison to engineers and the collaborative learning environment contributed to positive student perceptions of the EDP.

**Feeling Like an Engineer**

During the EDP, all student participants readily embraced their roles as engineers. When asked how the process helped them to feel like engineers, students responded:
• I felt like an engineer because it made me feel smart to use the process, I think that engineers are smart. (Student F)

• Coming up with my own creative ideas and being able to create them in all different ways, that made me feel like an engineer. (Student G)

• I was able to build stuff and I was trying different techniques to get it to work. (Student D)

• I think of an engineer as being someone who tries a lot to get something to work. My group did that. (Student A)

A trend among responses included students’ feeling as if they were engineers because they followed steps that an engineer would actually take in real-world situations. Students indicated that being able to act as an engineer in the classroom allowed them to truly feel as if they were engineers. Additional responses include:

• The different steps of the engineering design process helped me understand the steps an engineer would actually take. (Student I)

• Using the steps of an engineer made me feel like I was actually an engineer. I felt like I was doing the same thing that a real engineer does. (Student E)

• It felt like we were following the steps that an engineer really does in real life. (Student H)

Student perceptions of engineers also led to changes in their career aspirations. During the first interview, eight of the 12 respondents felt they could be an engineer, although three qualified they were not necessarily interested in doing so. At the conclusion of the study, all but one respondent (Student F) asserted they were capable of being an engineer. While 11 of the participants were confident in their abilities to become engineers, few
expressed a career aspiration that involved engineering. Their aspirations included working in education, the social sciences, business, writing, architecture, and medicine.

Two students (Students A and C) transformed their career aspirations to include engineering. Student A, who had previously wanted to be a veterinarian, conceded that they also found biomedical engineering to be interesting and that they could see themselves working to develop prosthetics for animals. Student C, who had initially expressed interest in playing a sport, developed an interest in working in engineering.

**Perseverance in Problem-Solving Through Collaborative Learning**

Working in small groups \( n = 12 \) allowed students to discuss ideas and provided peer support, which contributed to positive learning experiences. Students reported that they preferred collaborative learning through statements such as:

- I like when I get to work with my classmates and do things like experiments. I don’t like when we have to be quiet and do worksheets or read about science on the computer. (Student K)
- I liked being able to work in a team and trying to solve a problem together. (Student A)
- The engineering design process helped me by letting me work with others to problem solve. I think that solving those problems helped me better understand what we were learning about in science. (Student D)

Students also noted that working with their peers allowed them to persevere through difficulties during the EDP. Students demonstrated resiliency by learning through failure and applying this knowledge to effectively complete design challenges. Student C noted
that their group tried often to get their designs to work—an attribute they associated with being an engineer. Five other students indicated how they persevered through difficulties:

- [The EDP] helped me by letting me do something over and over until we got it to work. (Student B)
- [My group] tried different techniques to get it to work. (Student D)
- When I was confused about how to solve one of our problems, we worked together to figure out a way that we could solve it. It didn’t work like we thought, but we tried to come up with something (Student G).
- When we created the debris cleaner and it fell apart, we went back and remade it and were able to get it to work. I was proud that we kept going and didn’t just get mad or quit. (Student J)

Applying different methods to attempt to solve a problem demonstrates students’ perseverance and commitment to solving the engineering design challenges.

**Influence of Affective States**

The EDP prompted positive and negative emotions among participants. My analysis concluded positive states accounted for 71.8% of coded affective states while negative states accounted for the remaining 28.2%.

The EDP’s positive influences included instances of pride and confidence. Student G had one of the most profound changes throughout the duration of the study; initially, this student stated they did not like science due to a lack of interest, doubt in their abilities, and poor grades. At the conclusion of the research, she stated, “I feel pretty good about doing this type of science because with my group we can come up with good
ideas and we’re really creative together. I feel good about science.” Six other students showcased pride in their group design through statements such as:

- I was proud of the engineering designs that my group was able to build. I like to create and make things, so I think that our designs were really creative and neat. (Student L)
- I was proud of our bridge design and how much it was able to hold. It was exciting to see it work! My group thought it would work, but we were still surprised. (Student E)

This idea was common among other participants as Student B noted feeling proud that their group was able to work together to develop solutions that included all members’ ideas. Completing a project made Student H “proud,” and the student noted their design worked much better than the group had anticipated. Student C echoed this statement regarding their wheelchair design, stating they were excited about its functionality and meeting the goal of the engineering design challenge. Student K also expressed being “proud that [their] design worked.” Another student noted that completing a design activity made them feel smart (Student L).

The level of difficulty in the design challenges also provided students with rich learning experiences that allowed them to reflect on their capabilities, as when Student I shared, “When an activity is harder, I feel better about myself when it works out.”

Students also indicated positive feelings of excitement and enjoyment. Student A indicated being “excited and happy” when learning science and Student H also noted feeling excited. Student B stated that science was “pretty fun,” while student C considered science to be “pretty cool.” Student D commented that science was “very fun
and exciting.” Two students demonstrated positive affective states at the success of their designs. Student C shared, “When our wheelchair design worked. I was excited,” and Student A noted, “I was excited that our design worked.”

In addition to recognizing the positive influence of affective states, I also observed the influence of negative affective states in some student responses. Student J demonstrated the influence of negativity on her attitudes toward science and engineering by noting that science was “overwhelming” and reporting feeling “mad” when unable to complete an assignment. Likewise, Student B felt “irritated” when unsuccessful.

Indicators of self-doubt were evident in the responses of three students. Student F noted they did not feel that they were good at science. Student J made a similar remark and recalled being required to retake a science test in the past, thus doubting their ability to become an engineer. During their initial interview, Student G indicated they did not believe in their abilities in science because they “didn’t understand it.”

Both positive and negative emotions influenced student feelings towards science and engineering. Negative emotions played a strong role in students’ perception of their abilities to succeed in science and engineering while positive emotions allowed students to demonstrate pride and excitement.

**Transformation of Student Learning Preferences**

The EDP engaged students in hands-on activities and problem-solving activities that allowed them to understand science principles more than traditional learning methods. During interviews, students were very vocal about their learning preference, comparing their use of the EDP to prior methods:
• I liked the hands-on stuff because it helps me remember stuff. I like hands-on more, I don’t like just talking about it and doing a few worksheets. I think that I learn better when I actually get to do something. (Student I)

• I liked science a lot better when we’ve done it recently because we were given a problem and got to use hands-on experiences instead of being given a worksheet or trying to teach ourselves with some directions. (Student B)

Student B also asserted that previous science learning experiences were confusing because she felt she lacked explanation and was merely answering questions.

Students also expressed their preference for active learning experiences, as opposed to being expected to memorize content. Supporting statements include:

• The engineering design process helped me by being hands-on and giving me something to do, not just asking me to memorize something. (Student L)

• I like experiments, not worksheets. (Student F)

• Having to solve a problem helped me learn better, instead of just reading about it. (Student E)

Students perceived the opportunity to create a product to showcase their learning and understanding of an academic concept as beneficial, as the following statements indicate:

• Being able to make things and build stuff made me better understand it [science]. When we could build the way that we could solve a problem, I think I was better than just trying to draw it or explain it. (Student K)

• Being able to make something let me see my ideas and understand how things worked. (Student C)
Student responses indicate an overall agreement that, prior to the implementation of the EDP, their science experiences were not interactive or hands-on. Students openly discussed their lack of interest in learning via worksheets, lectures, or merely reading about science. Students also indicated such methods were not as beneficial to their own personal learning experiences. Student K specifically felt science had not been taught as frequently prior to the onset of the study, stating they felt they were able to learn more because “we’ve been able to do more science than we used to.”

**Summary of Findings**

This action research study sought to determine if the use of the EDP in fifth-grade science classrooms could impact female achievement and self-efficacy in science and engineering. Quantitative and qualitative data paint a detailed, robust portrait against two research questions. This 6-week study, implemented in the late Spring of 2023, indicated the EDP positively impacted student achievement and science and engineering self-efficacy.
CHAPTER 5: DISCUSSION, IMPLICATIONS, AND LIMITATIONS

This research constituted an intervention in rural, fifth-grade science classrooms to increase female achievement and self-efficacy in science and engineering. A decline in female performance on standardized science and engineering assessments initiated the need for a change. The overarching goal of this research was to address two questions:

1. How can use of the EDP improve fifth-grade, rural, female students’ achievement in science and engineering standards?
2. What is the effect of female students’ use of the EDP on their science and engineering self-efficacy?

Both quantitative and qualitative data contributed to addressing the research questions.

This chapter is divided into four sections. The first section discusses the findings and results of the study, utilizing literature to support the impact of the use of the EDP. The second section provides practical recommendations and implications for the use of the EDP in rural classrooms. The third section focuses on limitations of the research, giving way to the final section that offers recommendations for future research.

Discussion

The EDP intervention made a positive impact on science and engineering achievement and science and engineering self-efficacy. The overall findings from this research align with the literature discussed in Chapter 2 and are also supported by additional scholarship.
Student Achievement and the EDP

Teachers can use engineering design as a strategy to encourage active learning by engaging students in efforts to solve authentic problems (Grubbs & Strimel, 2015). Research suggests design-based learning supports the learning of science (Bethke Wendell & Rogers, 2013; Li et al., 2016;). Further research asserts that including engineering design in instruction leads to improved academic achievement (Arik & Topcu, 2022; Dohn, 2013; Park et al., 2018; Schnittka & Bell, 2011). The findings from the quantitative data support the idea that the EDP has a positive academic impact on student achievement in science and engineering.

The comparison of pre and post assessment scores, with a mean score increasing from 14.79 points to 18.67 points, indicate a significant change \((p = 0.009)\) between administrations. As research suggests that both female students and students of color are less likely than White male students to graduate with STEM degrees (Russell, 2017), understanding differences among races is imperative. I found no statistical significance among the assessment scores of students from four racial groups. However, this lack of significance could reflect the low number of participants.

Comparison of the checkpoint assessments, designed as formative measures of student achievement following the completion of a design activity, illuminated whether the EDP impacted student academic growth during the study. The mean score for the first checkpoint, 2.82, increased to 3.41 for the second checkpoint. A subsequent paired \(t\)-test found statistically significant results were found with a \(p\)-value of <0.001. This result indicates that student scores increased after each design activity.
Van Gompel (2019) found that the EDP can promote academic content retention by allowing students to create physical representations of their learning. My study supports this finding with students’ statements during semi-structured interviews. After the EDP intervention, I asked students to explain how the process helped them to understand what they were learning about in science. Student B stated that physically building a solution let her “really see [her] ideas and understand how things worked,” while Student K responded “Being able to make things and build stuff made me better understand it.”

A study of undergraduate pre-service teaching programs found a correlation between self-efficacy, expected GPA, and actual GPA (Nasir & Iqbal, 2019). Academic self-efficacy had a positive impact on academic performance, but the researchers cautioned, “over estimation of one’s capabilities may deteriorate effort level resulting in lower than expected performance” (Nasir & Iqbal, 2019, p. 40). My study recorded students’ anticipated grades using the S-STEM survey for language arts, math, and science. Comparing the total scores surfaced no significant change between administrations, with predicted averages maintaining a median of 7.0 and a p-value of 0.074. The results indicate that overall, most students felt they would score between “Somewhat Well” and “Very Well” in these academic areas. Because students can access a digital gradebook updated in real time, they may have already been aware of their science grade, reporting the actual status opposed to an anticipated grade.

**Science and Engineering Self-Efficacy and the EDP**

Quantitative and qualitative data support the use of the EDP in upper-elementary classrooms by indicating a positive influence on fifth-grade girls science and engineering
self-efficacy. While improving academic achievement, the EDP can also improve attitudes toward science (Capobianco et al., 2018). Because girls begin losing both interest and confidence in science and engineering in elementary school (Hunt et al., 2021), reaching such students during this critical period is vital. The EDP intervention positively impacted students’ attitudes towards STEM subjects, with an overall total median score of 147.0 on the first administration and an overall median score of 155.0 for the second. Analysis using the Wilcoxon signed-rank test yielded a Z value of -2.576, while the p-value was 0.010. I thus concluded a statistical significance exists between the two sets of data. When comparing the subscales of the survey across both sets of data, areas of science attitudes (original median of 30.0, second median of 31.0) presented a statistically significant change from the first and second administration of the survey. Engineering and technology attitudes had an original median of 32.0 that decreased to 31.0 with a p-value of 0.165. A significant statistical change was not evident.

Gruber-Hine (2018) suggested the integration of engineering curriculum at the elementary level would benefit students by building on 21st-century skills. Specifically, the EDP in this study included critical thinking, problem-solving, creativity, and global awareness. During the engineering design challenges, students were tasked with linking their knowledge of science content and engineering practices to solve real-world problems. Students had to make connections and solve problems. Students exhibited creativity through their unique use of materials to construct solutions to the engineering design challenges. Students developed a broader understanding of global awareness during the ocean debris challenge as they were required to address the pollution issue evident in the world’s oceans. Data from the S-STEM survey support this idea. Students’
confidence with 21st-century skills increased significantly throughout the duration of the study. The median increased from 45.0 to 47.0 with a calculated $p$-value of 0.009.

As Hachey et al. (2021) noted, engineering and technology are rarely taught in elementary classrooms. While engineering standards are often included in science academic standards, like the NGSS (NGSS Lead States, 2013), they are seldom integrated into lessons as intended (Thompson, 2017). S-STEM survey results indicated a lack of interest in engineering careers. These quantitative results also align with the interview responses to the question, “How do you feel about the following statement? I could be an engineer someday.” Of the 12 students interviewed, 91.6% ($n = 11$) indicated they felt capable of being an engineer, although only five (45.5%) showcased any interest in doing so. One respondent, Student F, stated she did not believe she could be an engineer because she did not feel successful at engineering.

I attribute the lack of a statistically significant result for engineering and technology attitudes to students’ lack of exposure to these areas and lack of understanding of engineering. Research suggests students have a limited understanding of engineering and the work that engineers do (Lampley et al., 2022). DiFrancesca et al. (2014) noted that teacher preparation programs focus on mathematics and sciences, only two components of STEM, often omitting technology and engineering. In turn, engineering is often absent in the classroom hindering elementary students’ understanding. Prior to the intervention, students had not participated in any engineering design challenge activities and had no exposure to engineering curriculum.

While students did show increased positive attitudes toward engineering, I suspect this 6-week intervention did not provide enough time and exposure to engineering to
transform student attitudes or allow students to fully understand the field of engineering. For instance, students repeatedly referenced “experiments” instead of “design challenges” during their interviews. Students answered survey questions based upon their preference for working in the field of engineering. While many students were confident in their abilities to be an engineer, many did not express a desire to do so.

**STEM Career Interest**

Research further suggests students tend to pursue careers that align with both their personal experiences and exposure to such areas (Elam et al., 2012). The results from Spearman’s rho test confirms this. The quantitative analysis of the S-STEM survey did not find a statistically significant change to student interest in STEM careers; median values increased from a score of 27.0 to 28.0 with a $p$-value of 0.518. I attribute this outcome to students’ lack of exposure to each of the 12 career areas and the fact that in-depth career exploration was not part of the EDP intervention. Analysis of the interviews reinforced this finding; while all students ascertained the importance of science and engineering as well as their abilities to work in engineering, only two students showcased changes to their career aspirations. Student A expressed a newfound interest in biomedical engineering, while Student C showed a new career interest in engineering. While four students expressed interest in medical fields, their interest in their future career did not change post-intervention.

Students’ expression of knowing adults in numerous STEM fields also did not exhibit any statistically significant changes between the first administration of the survey and the second, with median scores of 8.0 and 9.0, respectively. The $p$-value from the Wilcoxon signed-rank test was 0.115. In their interviews, four students did allude to role
models when discussing potential future career interest, —including older siblings, a teacher, and parents. I attribute the lack of statistically significant change for this section of the survey to the fact that the 6-week intervention did not explicitly introduce students to STEM professionals, although students may have been exposed to adults in STEM careers outside of the classroom. Using Spearman’s rho test, I determined a significant difference does exist between students’ personally knowing adults in STEM career fields and overall self-efficacy with the $p$-value at 0.006.

**Impact of the EDP in Elementary Education**

Literature supports that the EDP provides a meaningful learning experience (English, 2016; Jia et al., 2021; Roehrig et al., 2012). Li et al. (2016) credited the EDP with increasing student’s problem-solving abilities. Likewise, the EDP intervention in this study elicited positive feedback from students; they frequently compared themselves to engineers and praised the collaborative learning environment. Students asserted that they felt like real engineers who were responsible for solving real problems. Student responses also indicated an appreciation for working collaboratively and including group members to ensure success in design challenges. Students also described how they persevered through difficult tasks and kept recreating their designs to overcome failure.

Analysis of the interview data illuminated students’ perceptions and overall impact of the EDP on the participants. Student statements support that the EDP increased their problem-solving abilities through the use of activities that allowed them to develop a physical solution to the problem. Students indicated they preferred hands-on, interactive methods of learning, as opposed to other methods like worksheets and memorization.
Students stated that following the steps of the EDP and working toward solving a problem helped them feel like actual engineers.

Student interview responses heavily demonstrated the influence of affective states on student’s self-efficacy when using the EDP. Affective states represented the highest percentage of coded responses. Physiological reactions impact self-efficacy by linking emotional and physical states to abilities (Rittmayer & Beier, 2008). Students portrayed a sense of pride in their accomplishments when using the EDP. Students were proud when their designs succeeded, but also when they completed a design, regardless of its success. The positive influence of affective states on self-efficacy reduces the impact of negative states and alters the way in which students interpret their experiences (Usher & Pajares, 2008). Such positive emotional states created positive perceptions of the EDP by students. Engineering design activities have demonstrably promoted student engagement and excitement (Cantrell et al., 2006). Students commonly used “excited” when referring to testing their designs.

Maltese et al. (2018) argued that understanding failure helps students to become more innovative. Students exhibited pride when they were able to persevere through a challenging time and develop new solutions. Students noted that facing difficulties during the engineering design process allowed them to work together more effectively in order to reach a viable solution.

As the EDP is cyclical, failure is an integral part of this process and students must understand its importance. This understanding allows students to perceive failure as a positive aspect of the learning process (Beavers et al., 2019). As students transform their relationship with failure, they learn that failure is an opportunity to improve a design and
learn how to apply this newfound knowledge to future challenges (Lottero-Perdue & Perry, 2019). Bandura (1977) argued that overcoming failures through effort can positively impact self-efficacy.

**Practical Recommendations and Implications**

This research has personal and professional implications. Implementing the EDP in a rural, upper-elementary classroom provided insight into the academic performance of female students as well as their perceptions toward science and engineering.

**Practical Recommendations**

Analysis of the qualitative and quantitative data suggests the EDP intervention had an overall positive impact on the participants. The results from this study support a district-wide change to the approach of teaching science, especially at the elementary level. There are three major recommendations derived from this study: shifting science instruction, effectively integrating engineering education, and protecting the instructional time of science.

One of the most prominent recommendations is to implement a change that impacts teaching strategies and the role of students in the classroom. The primarily teacher-centered classroom environment must transform into a student-centered learning space that promotes creativity and critical thinking skills by providing students with opportunities to solve problems. Students expressed a lack of interest in science couched in traditional methods, including rote activities, worksheets, and non-collaborative classroom settings. When given the opportunity to work together, students were engaged, excited, and engrossed in the learning process. Experiential learning activities allow learners to build conceptual understandings (Horrace & Stone, 2023) and research
suggests students learn best through active learning processes that allow them to engage in meaningful learning experiences (Horrace & Stone, 2023; Parker et al., 2022).

Integrating engineering education in elementary classrooms is also important to students’ continued growth. Engineering education is currently not a defined portion of the elementary science curriculum and engineering practices are only included in science standards of learning. The blending of science and engineering instruction within NGSS provides an avenue for students to apply their science knowledge in real-world scenarios, thus linking the two domains (Christian et al., 2021; NGSS Lead States, 2013). Although my state does not utilize this framework, it is worth exploring to help teachers understand how the science and engineering principles are integrated into state standards.

Effectively integrated engineering education will require resources, time, and dedication on the part of the district, school administration, and teachers. As teacher preparation programs generally do not provide any courses in engineering education, districts must provide professional development. Hynes (2012) noted that teachers need some sort of preparation to teach engineering and engineering design. Without proper training, teachers are likely to lack the confidence to integrate engineering into their curriculum and may be uncomfortable, thus avoiding teaching engineering concepts (Hammack & Ivey, 2019). Science teachers often lack a working knowledge of science curriculum as well as effective teaching strategies, exhibiting low confidence and self-efficacy in the teaching of science (Lewis et al., 2014).

As the current state standards have a specific standard related to science and engineering principles at each grade level, it is imperative that these are integrated into science lessons. Teachers must also be cognizant of how these engineering principles can
be integrated into science curriculum rather than teaching engineering in isolation from other subjects. Teachers could use the curriculum in this intervention to teach science and engineering concepts as well as showcase how the two content areas are integrated.

In addition to integrating engineering education into curriculum, teachers should also provide opportunities to learn about careers related to engineering, as results of the S-STEM survey and interviews linked interest in STEM fields to being familiar with adults in those particular fields. Hosting a STEM Career Fair Day would benefit all students by exposing them to engineers and introducing various careers that they may otherwise not be aware of.

Another vital recommendation is to provide protected instructional time for science. With a district-wide focus on literacy and math, science receives less than half the weekly instructional time of reading or math, and students may lack daily science instruction. In fourth grade, history is state-tested and thus often supplants science. Other school systems have decreased the amount of instructional time for elementary science (Haverly et al., 2022; Smith, 2020) to focus on reading and math. School systems must take evidence-based decision making into account and understand the implications of reducing the amount of time spent on science instruction.

The lack of focus on STEM education remains a concern for the United States as educated STEM learners are important to the future of the country by improving the overall well-being of society through the development of 21st-century learners (Eisenhart & Weis, 2022). Student exposure to science and engineering leads to improved interest and attitudes in these areas as well as prepares students to potentially pursue careers in these disciplines (El Sayary et al., 2015).
Implementation Plan

To share the findings from this study, the EDP’s positive impact on science and engineering achievement and self-efficacy, I will use various methods. As this research was conducted within the school, I will first share the outcome as a means to implement changes at the local level, specifically by reporting to the current fourth- and fifth-grade science teachers. I will also share results directly with school administrators who oversee the academic operations of the building, and the district instructional specialist for science, who manages science curriculum as a whole across the entire district. The instructional specialist’s understanding of the impact of this study could drive change throughout the district. I must also provide the results directly to the Superintendent as the district currently has a vacancy for the Director of Elementary Education. I also will draw school and district officials’ attention to the fact that the female pass rate for the 2022–2023 school year was 56.52%, compared to 47.83% from the previous year. The gender gap also decreased with males having a pass rate of 70.59%, compared to 82.76% for the previous year.

Putting these findings into action requires active implementation of the EDP in science classrooms and continuing the conversation throughout the school year and further. One method of reaching the audience of the school is providing on-going professional development sessions to teachers throughout the school year. The first session will aim to describe the EDP, while subsequent sessions will include the development of an engineering design challenge that is relevant to the students of the particular teachers. I will also reserve time to model the use of the EDP in the classroom showing teachers how to implement the process.
I will also share these results through larger platforms outside the district. The state department of education is in the process of developing an initiative to increase the implementation of computer science standards across K–8 classrooms. The use of the EDP could assist in implementing these standards, including areas of computational thinking. Presenting this study at a state-wide conference that focuses on technology education would allow stakeholders at the local, district, and state level to bring these findings back to their own classrooms and districts. I also intend to share these results at the annual meeting for the state association of science teachers.

**Reflection**

Completing this action research has been an eye-opening experience. Not only has it allowed me to explore the deficiencies that exist in science classrooms in my own district, but it has also provided me with insight into the importance of student perceptions in the science classroom. I have spent many years as a classroom educator, teaching a variety of subjects, primarily science. During the duration of this dissertation, I relocated and changed my role, moving into more of an instructional coaching position where I focus on the integration of technology in classrooms. This study allowed me to reconnect with students and dive into their perceptions in the classroom as well as further understand the plights facing educators and students in rural communities.

In general, this study proceeded as I anticipated. The results affirmed my belief in the power of the EDP, backed by previous research. I expected to find increased achievement and self-efficacy. However, a few surprises emerged from my analysis of the data, such as that science self-efficacy showed a statistically significant increase while engineering self-efficacy showed an increase that was not statistically significant. I
anticipated a significant increase in both areas. I also anticipated students would feel the EDP helped them to learn and allowed them to feel as if they were a part of the learning process, sparking creativity and critical thinking.

The immersion and engagement of students within their learning environment was evident. I observed students fully engrossed in the physical environment of the classroom as they utilized available tools and materials to solve design challenges. Students showcased decision making when determining materials to utilize and appreciated the ability to choose their own materials. I suspect that the physical environment of the makerspace-style classroom impacted the results of this study and results may differ if this study were conducted outside of this type of classroom environment.

The interviews with students also provided a great deal of insight into the approach to science in elementary classrooms. While these findings were not surprising, they were frustrating. Students clearly communicated that they enjoyed the EDP and felt it assisted them in learning science content, much more than the traditional teaching methods of worksheets and rote activities to which they were accustomed. To me, this amplifies science teachers’ lack of instructional support in my district as well as a lack of understanding of best practices for teaching science. Pushing science aside to emphasize literacy and math is disheartening. The conversations with students, and exploring the classroom from their words, has prompted me to advocate on their behalf. I have joined both the science committee and leadership team at the school in an attempt to steer the progression of science education.

Conducting this study at numerous sites in the district would strengthen its results, documenting a widespread problem as opposed to an isolated case. This research could
also be strengthened by adding in other upper-elementary grade levels, namely third and fourth grade. Consistent results across grade levels may warrant a stronger response from district administration.

**Limitations**

Limitations do exist in this research. These include: timing, the number of participants, the single research site, lack of general resources, and lack of physical time. Each limitation possibly contributed to the findings and is worth consideration when examining the results.

Due to district time constraints, standardized testing windows, and the lengthy process to obtain district approval, I began the at the start of the fourth quarter of the school year. The fourth quarter often includes schedule changes and disruptions in the normal learning process due to typical end-of-year activities. The number of participants and isolated location of this study also may have impacted the results. Gathering data from a larger group of students, across the district, would have provided more responses as well as a more diverse population; only four students of color participated in this study. Potential bias may also exist due to a homogeneous teacher team. Like me, the two science teachers are White women.

Physical time and resources provided another limitation. Prior to the implementation of this study, science was not taught daily; it shared a portion of instructional time with social studies. This study provided a protected amount of science time each day during its duration, yet more time would have allowed students to revisit their solutions and continue to improve their engineering design solutions. Additional time may have increased communication and collaboration between groups of students,
allowing each group to analyze and critique others’ solutions. Access to more advanced resources would have also benefitted this study. Grubbs and Strimel (2015) noted that the ability to utilize proper “materials, tools, and resources can be challenging” (p. 81), but these are imperative to provide students with authentic experiences. Moreover, while these design activities were understood and applicable to the students of The Point Elementary, exploring engineering design activities directly linked to the school itself may have yielded different results.

**Recommendations for Future Research**

Recommendations for future research include integration of the EDP across various subjects as academic subjects do not exist in isolation in the real-world (Kelley & Knowles, 2016). Jia et al. (2021) recommended truly integrating design activities across many content areas rather than merely pairing different standards. Use of the EDP in other academic areas would provide deeper insight into its overall impact on student learning and self-efficacy. I also recommend using the EDP outside of a makerspace-style environment as the physical environment likely had an influence on the results of this study.

Another recommendation is that engineering design challenges must be relevant to the learner, including their age and understanding. Regarding younger students, incorporating understandable problems and content is also vital to successful use of the EDP. I further recommend giving students opportunities to explore careers related to engineering, which has the potential to impact student interest in these fields.

Future research should focus on rural elementary students as much of the research for rural students focuses on secondary education (Johnson et al., 2021). As students’
perceptions change over time, understanding them at each stage of their education is imperative. Much of the rural population research centers career pathways and post secondary education. The importance of these areas notwithstanding, understanding the pathways that pave the way to postsecondary education is also important.

Summary

This action research study explored the impact of the EDP on engineering and science achievement and self-efficacy for fifth-grade female students in a rural elementary school. Qualitative and quantitative data established that the EDP positively impacted student achievement and self-efficacy. This study provided insight into promising practices for student learning and how classroom interactions can influence student attitudes toward science and engineering.
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### APPENDIX A: UNIT LESSON PLANS

<table>
<thead>
<tr>
<th>Grade Level</th>
<th>5th</th>
</tr>
</thead>
</table>
| Standards   | **Force, Motion, Energy, and Matter**  
|             | 5.3 The student will investigate and understand that there is a relationship between force and energy of moving objects. Key ideas include:  
|             | a. Moving objects have kinetic energy;  
|             | b. Motion is described by an object’s direction and speed;  
|             | c. Changes in motion are related to net force and mass;  
|             | d. When objects collide, the contact forces transfer energy and can change objects’ motion; and  
|             | e. Friction is a force that opposes motion  
|             | **Scientific and Engineering Practices**  
|             | 5.1 The student will demonstrate an understanding of scientific and engineering practices by –  
|             | a. Asking questions and defining problems  
|             | b. Planning and carrying out investigations  
|             | c. Interpreting, analyzing, and evaluating data  
|             | d. Constructing and critiquing conclusions and explanations  
|             | e. Developing and using models  
|             | f. Obtaining, evaluating, and communicating information |
### Objectives

Students will understand that friction is a force that opposes motion and that different objects have different amounts of friction. Rougher surfaces have more friction between them and heavier objects have more friction because they press together with greater force.

Students will understand that motion describes an object's direction and speed.

Students will be able to identify forces acting on objects that cause them to move as well as distinguish between kinetic and potential energy.

Students will work together collaboratively to develop a solution to a design challenge and understand that the design process is an iterative, cyclic process.

### Lesson Overview

All students will complete the S-STEM Initial Survey in Google Forms. Students will also complete the pre-assessment in Google Forms.

Students will be introduced to the Engineering Design Process using the created Nearpod. This serves as an introduction to the design process, covering each of the main sections of the process and explaining these to students. Students need to have a general understanding of each step to understand its importance to the process as a whole. This will include class discussions, answering review/checkpoint questions as well as a video from Engineering is Elementary that shows an example of this process.

**Wheelchair Activity**

**Career Connection: Rehabilitation Engineer**

Students are tasked with developing a wheelchair model that can travel across three different terrains while holding a person (simulated by a doll); students have constraints of both time and only access to the materials in the classroom makerspace.

Students will research the problem, brainstorm potential solutions, design a solution, create, and test out their models. Models will be tested by using a spring scale to move models across each individual (simulated) terrain. Results will be recorded and a graph created from these results; students will then identify the independent and dependent variable. Students will reflect on practices as well as communicate their results to the class.

### Assessment

Pre-Assessment

Checkpoint 1
<table>
<thead>
<tr>
<th>Grade Level</th>
<th>5th</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vocabulary</td>
<td>Continental Shelf, Trench, Continental Slope, Ocean Ridge, Abyssal Plain</td>
</tr>
</tbody>
</table>
| Standards   | Earth/Space Systems and Earth Resources  
4.7 The student will investigate and understand that the ocean environment has characteristics. Key characteristics include  
  a. Geology of the ocean floor  
  b. Physical properties and movement of ocean water |
| Scientific and Engineering Practices | 5.1 The student will demonstrate an understanding of scientific and engineering practices by –  
  a. Asking questions and defining problems  
  b. Planning and carrying out investigations  
  c. Interpreting, analyzing, and evaluating data  
  d. Constructing and critiquing conclusions and explanations  
  e. Developing and using models  
  f. Obtaining, evaluating, and communicating information |
| Objectives  | Students will be able to identify the features of the ocean floor, understanding its basic geology. Students will understand the physical properties and movement of the ocean water. Students will work to develop a way to clean pollution, understanding the different physical barriers that are present on the ocean floor.  
Students will work together collaboratively to develop a solution to a design challenge. Students will understand that the design process is an iterative, cyclic process. |
| Lesson Overview | Ocean Debris Cleaner  
Career Connection: Environmental Engineer  
Students are tasked with developing a prototype that will effectively clean debris from a model of the ocean. The model is designed to reflect the geological features of the ocean floor. Students have constraints of both time and only access to the materials in the classroom makerspace. Students will research the problem, brainstorm potential solutions, design a solution, create, and test out their models. Models will be tested out by placing them in the water and determining how much debris they can clean within a one-minute time period. Group results will be recorded as well as class results recorded to compare designs. Students will reflect on practices as well as communicate their results to the class. |
<p>| Assessment  | Checkpoint 2 |</p>
<table>
<thead>
<tr>
<th>Grade Level</th>
<th>5th</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topic</td>
<td>Engineering Design Process – S/E Practices</td>
</tr>
<tr>
<td>Vocabulary</td>
<td>Constraint, Requirement</td>
</tr>
</tbody>
</table>
| Standards   | **Scientific and Engineering Practices**  
5.1 The student will demonstrate an understanding of scientific and engineering practices by –  
   a. Asking questions and defining problems  
   b. Planning and carrying out investigations  
   c. Interpreting, analyzing, and evaluating data  
   d. Constructing and critiquing conclusions and explanations  
   e. Developing and using models  
   f. Obtaining, evaluating, and communicating information |
| Objectives  | Students will apply their knowledge of science and engineering practices to use tools and materials to develop a device that meets a specific problem. |
| Lesson Overview | Bridge Building  
Career Connection: Civil Engineer  

Students are tasked with developing a model of a bridge that will successfully span across a given distance and support weight. Students have constraints of both time and only access to the materials in the classroom makerspace. Students will research the problem, brainstorm potential solutions, design a solution, create, and test out their models. Models will be tested by placing the model across two objects to allow them to span a particular distance and then by adding weight until the design collapses. Group results will be recorded. Students will reflect on practices as well as communicate their results to the class. |
| Assessment  | Post-Assessment |
APPENDIX B: STUDENT WORK SAMPLES

Figure A.1 Student Work Samples
APPENDIX C: PRE-POST ASSESSMENT

1. Which objects are demonstrating kinetic energy?

2. A student rolls a ball on the ground. Which of these causes the ball to slow down and then stop?
   
   A. The motion of the ball  
   B. The speed of the ball  
   C. Friction from the ground  
   D. A magnetic field
3. The box would be easier to move if the surface of the ramp was smoother because there would be less —

A. Mass in the box
B. Friction opposing the box
C. Gravity pulling on the box
D. Distance to push the box

4. The ocean floor:

A. Is always a flat bed of sand
B. Covers less area than the land
C. Has mountains, plains, and ridges like land surfaces
D. Is covered by the same amount of water everywhere

5. Based on the table, how much rainfall should a scientist have predicted for May of 2011 in [Town]?

A. 12–17 inches
B. 15–20 inches
C. 18–23 inches
D. 21–26 inches
6. Which of these increases as a submarine dives deeper into the ocean?

A. The number of plants in the water
B. The freshness of the water
C. The water temperature
D. The water pressure

7. Which of these increases as a submarine dives deeper into the ocean?

A. The number of plants in the water
B. The freshness of the water
C. The water temperature
D. The water pressure

8. Which diagram correctly identifies the force of friction on the box?

A. 
B. 
C. 
D. 

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9. Algae and other producers need lots of sunlight. More ocean algae would be found in the water:

A. Above the continental shelf  
B. On the abyssal plain  
C. In the oceanic trench  
D. Beside the continental slope

10. When a coin is dropped, it falls to the ground. As the coin falls, it loses potential energy and gains what kind of energy?

A. Kinetic  
B. Solar  
C. Chemical  
D. Electrical

11. Which location is likely to have the greatest water pressure, the coldest temperatures, and the smallest number of living organisms?

A. 1  
B. 2  
C. 3
12. What kind of energy do all moving objects have?
   A. Light energy
   B. Renewable energy
   C. Kinetic energy
   D. Solar energy

13. Lobster pots are used by fishermen to catch lobsters in shallow water. In which area of the ocean would commercial fishermen most likely place their lobster pots?
   A. On the bottom of the ocean trench
   B. On top of a mid-ocean ridge
   C. On the continental slope
   D. On the continental shelf

14. Which picture shows the book with the most potential energy?

   A. 
   B. 
   C. 
   D. 

15. Which best describes the part of the ocean called the continental shelf?
   A. Flat underwater valley
   B. A region of mountains in the deep ocean
   C. A shallow area of sediment near the shore
   D. A region with a higher water pressure
16. A student made a track for a toy sled using 4 different materials. At which section of the track is friction most likely to cause the greatest resistance to the motion of the toy sled?

A. 1  
B. 2  
C. 3  
D. 4

17. The diagram shows a model of the ocean floor. Which number identifies the continental slope?

A. 1  
B. 2  
C. 3  
D. 4
18. What is the mass of the rock shown?

Your answer: _____

19. Which of these are the deepest parts of the ocean?

A. Continental shelves
B. Continental slopes
C. Ocean trenches
D. Abyssal plains
A student is investigating the time it takes for different objects to reach the ground after they are dropped. The constant in this investigation is the –

A. Time to reach the ground
B. Distance to the ground
C. Weight of each object
D. Object being dropped
21. A student made the model showing the particles in a solid. To improve the model the student should –

A. Put the beads in a square container
B. Take out the beads so the particles can move more easily
C. Shake the container gently to show how the particles vibrate
D. Use different colored beads to make the particles easier to see

22. A student conducted an investigation testing the strength of an electromagnet. The dependent variable in this investigation was the –

A. Voltage of the battery
B. Length of the insulated wire
C. Number of paperclips attracted
D. Number of times the wire was coiled
23.

Based on the mineral identification table, which mineral belongs in square X of the flow chart?

A. Mica
B. Graphite
C. Magnetite
D. Hornblende

24.

Based on the mineral identification table, which mineral belongs in square X of the flow chart?

A. Mica
B. Graphite
C. Magnetite
D. Hornblende

25. Students used a stopwatch to time the number of second(s) that a vehicle took to move forward 6 meters (m) on two different surfaces. They performed six trials
for each surface, using the same vehicle and moving the vehicle as fast as it would go. The data is shown in the figure.

Based on the average time in the data tables, on Surface 1, the vehicle moved:

A. Faster than it moved on Surface 2
B. Slower than it moved on Surface 2
C. Farther than it moved on Surface 2
D. At the same speed as it moved on Surface 2
APPENDIX D: CHECKPOINT #1

1. Which objects are demonstrating kinetic energy?

2. Which picture shows an object that has kinetic energy?

A

B

C

D
3. A bicyclist rides on a flat road and then stops pedaling but does not apply the brakes. The bicycle stops because of —

A. Balance  
B. Friction  
C. Attraction  
D. Magnetism

4. Which diagram correctly identifies the force of friction on the box?

A.  
B.  
C.  
D.  

5. A student made a track for a toy sled using 4 different materials. At which section of the track is friction most likely to cause the greatest resistance to the motion of the toy sled?

A. 1  
B. 2  
C. 3  
D. 4
APPENDIX E: CHECKPOINT #2

1. At which location are oceans the deepest?
   A. Mid-ocean ridge
   B. Abyssal plain
   C. Ocean trench
   D. Volcanic island

2. The diagram shows a model of the ocean floor. Which number identifies the continental slope?
   A. 1
   B. 2
   C. 3
   D. 4

3. Based on the table, how much rainfall should a scientist have predicted for May of 2011 in [Town]?
   A. 15–20 inches
   B. 12-17 inches
   C. 18–23 inches
   D. 21–26 inches
4. The mass of the rock shown is:

Your answer: ______

5. Which best describes the part of the ocean called the continental shelf?

A. Flat underwater valley
B. A region of mountains in the deep ocean
C. A shallow area of sediment near the shore
D. A region with a higher water pressure
APPENDIX F: S-STEM SURVEY

Upper Elementary School Student Attitudes Toward STEM (S-STEM) – Grades 4–5

Directions:
There are lists of statements on the following pages. Please mark your answer sheets by marking how you feel about each statement. For example:

<table>
<thead>
<tr>
<th>Example 1:</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither Agree nor Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>I like engineering.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>

As you read the sentence, you will know whether you agree or disagree. Fill in the circle that describes how much you agree or disagree.

Even though some statements are very similar, please answer each statement. This is not timed; work fast, but carefully.

There are no “right” or “wrong” answers! The only correct responses are those that are true for you. Whenever possible, let the things that have happened to you help you make a choice.

Please fill in on only one answer per question.

Friday Institute for Educational Innovation (2012). Upper Elementary School Student Attitudes Toward STEM Survey.
<table>
<thead>
<tr>
<th>Math</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither Agree nor Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Math has been my worst subject.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>2. I would consider choosing a career that uses math.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>3. Math is hard for me.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>4. I am the type of student to do well in math.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>5. I can handle most subjects well, but I cannot do a good job with math.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>6. I am sure I could do advanced work in math.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>7. I can get good grades in math.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>8. I am good at math.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Science</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither Agree nor Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>9. I am sure of myself when I do science.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>10. I would consider a career in science.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>11. I expect to use science when I get out of school.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>12. Knowing science will help me earn a living.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>13. I will need science for my future work.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>14. I know I can do well in science.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>
15. Science will be important to me in my life’s work. | ○ | ○ | ○ | ○ | ○ |
16. I can handle most subjects well, but I cannot do a good job with science. | ○ | ○ | ○ | ○ | ○ |
17. I am sure I could do advanced work in science. | ○ | ○ | ○ | ○ | ○ |

**Engineers** use math, science, and creativity to research and solve problems that improve everyone’s life and to invent new products. There are many different types of engineering, such as chemical, electrical, computer, mechanical, civil, environmental, and biomedical. Engineers design and improve things like bridges, cars, fabrics, foods, and virtual reality amusement parks. **Technologists** implement the engineering designs that engineers develop; they build, test, and maintain products and processes.

| 18. I like to imagine creating new products. | Strongly Disagree | Disagree | Neither Agree nor Disagree | Agree | Strongly Agree |
| 19. If I learn engineering, then I can improve things that people use every day. | ○ | ○ | ○ | ○ | ○ |
| 20. I am good at building and fixing things. | ○ | ○ | ○ | ○ | ○ |
| 21. I am interested in what makes machines work. | ○ | ○ | ○ | ○ | ○ |
| 22. Designing products or structures will be important for my future work. | ○ | ○ | ○ | ○ | ○ |
| 23. I am curious about how electronics work. | ○ | ○ | ○ | ○ | ○ |
24. I would like to use creativity and innovation in my future work.  ○  ○  ○  ○  ○

25. Knowing how to use math and science together will allow me to invent useful things.  ○  ○  ○  ○  ○

26. I believe I can be successful in a career in engineering.  ○  ○  ○  ○  ○

### 21st Century Skills

<table>
<thead>
<tr>
<th></th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither Agree nor Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>27. I am confident I can lead others to accomplish a goal.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>28. I am confident I can encourage others to do their best.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>29. I am confident I can produce high quality work.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>30. I am confident I can respect the differences of my peers.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>31. I am confident I can help my peers.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>32. I am confident I can include others’ perspectives when making decisions.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>33. I am confident I can make changes when things do not go as planned.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>34. I am confident I can set my own learning goals.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>35. I am confident I can manage my time wisely when working on my own.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>
36. When I have many assignments, I can choose which ones need to be done first.

37. I am confident I can work well with students from different backgrounds.

**Your Future**

Here are descriptions of subject areas that involve math, science, engineering and/or technology, and lists of jobs connected to each subject area. As you read the list below, you will know how interested you are in the subject and the jobs. Fill in the circle that relates to how interested you are. There are no “right” or “wrong” answers. The only correct responses are those that are true for you.

<table>
<thead>
<tr>
<th>Subject Area</th>
<th>Not at all Interested</th>
<th>Not So Interested</th>
<th>Interested</th>
<th>VeryInterested</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. <strong>Physics:</strong> is the study of basic laws governing the motion, energy, structure, and interactions of matter. This can include studying the nature of the universe. <em>(aviation engineer, alternative energy technician, lab technician, physicist, astronomer)</em></td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>2. <strong>Environmental Work:</strong> involves learning about physical and biological processes that govern nature and working to improve the environment. This includes finding and designing solutions to problems like pollution, reusing waste and recycling. <em>(pollution control analyst, environmental engineer or scientist, erosion control specialist, energy systems engineer and maintenance technician)</em></td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>3. <strong>Biology and Zoology</strong>: involve the study of living organisms (such as plants and animals) and the processes of life. This includes working with farm animals and in areas like nutrition and breeding. <strong>(biological technician, biological scientist, plant breeder, crop lab technician, animal scientist, geneticist, zoologist)</strong></td>
<td>Not at all Interested</td>
<td>Not So Interested</td>
<td>Interested</td>
<td>Very Interested</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>4. <strong>Veterinary Work</strong>: involves the science of preventing or treating disease in animals. <strong>(veterinary assistant, veterinarian, livestock producer, animal caretaker)</strong></th>
<th>Not at all Interested</th>
<th>Not So Interested</th>
<th>Interested</th>
<th>Very Interested</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>5. <strong>Mathematics</strong>: is the science of numbers and their operations. It involves computation, algorithms and theory used to solve problems and summarize data. <strong>(accountant, applied mathematician, economist, financial analyst, mathematician, statistician, market researcher, stock market analyst)</strong></th>
<th>Not at all Interested</th>
<th>Not So Interested</th>
<th>Interested</th>
<th>Very Interested</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>6. <strong>Medicine</strong>: involves maintaining health and preventing and treating disease. <strong>(physician’s assistant, nurse, doctor, nutritionist, emergency medical technician, physical therapist, dentist)</strong></th>
<th>Not at all Interested</th>
<th>Not So Interested</th>
<th>Interested</th>
<th>Very Interested</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>7. <strong>Earth Science</strong>: is the study of earth, including the air, land, and ocean. <strong>(geologist, weather forecaster, archaeologist, geoscientist)</strong></th>
<th>Not at all Interested</th>
<th>Not So Interested</th>
<th>Interested</th>
<th>Very Interested</th>
</tr>
</thead>
</table>
8. **Computer Science**: consists of the development and testing of computer systems, designing new programs and helping others to use computers. (*computer support specialist, computer programmer, computer and network technician, gaming designer, computer software engineer, information technology specialist*)

<table>
<thead>
<tr>
<th>Not at all Interested</th>
<th>Not So Interested</th>
<th>Interested</th>
<th>Very Interested</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>9. Medical Science</strong>: involves researching human disease and working to find new solutions to human health problems. (<em>clinical laboratory technologist, medical scientist, biomedical engineer, epidemiologist, pharmacologist</em>)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Not at all Interested</th>
<th>Not So Interested</th>
<th>Interested</th>
<th>Very Interested</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>10. Chemistry</strong>: uses math and experiments to search for new chemicals, and to study the structure of matter and how it behaves. (<em>chemical technician, chemist, chemical engineer</em>)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Not at all Interested</th>
<th>Not So Interested</th>
<th>Interested</th>
<th>Very Interested</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>11. Energy</strong>: involves the study and generation of power, such as heat or electricity. (<em>electrician, electrical engineer, heating, ventilation, and air conditioning (HVAC) technician, nuclear engineer, systems engineer, alternative energy systems installer or technician</em>)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Not at all Interested</th>
<th>Not So Interested</th>
<th>Interested</th>
<th>Very Interested</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>12. Engineering</strong>: involves designing, testing, and manufacturing new products (like machines, bridges, buildings, and electronics) through the use of math, science, and computers. (<em>civil, industrial, agricultural, or mechanical engineers, welder, automechanic, engineering technician, construction manager</em>)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Not at all Interested</th>
<th>Not So Interested</th>
<th>Interested</th>
<th>Very Interested</th>
</tr>
</thead>
</table>
**About Yourself**

1. How well do you expect to do this year in your:

<table>
<thead>
<tr>
<th></th>
<th>Not Very Well</th>
<th>OK/Pretty Well</th>
<th>Very Well</th>
</tr>
</thead>
<tbody>
<tr>
<td>English/Language Arts Class?</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Math Class?</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Science Class?</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>

2. More about you.

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
<th>Not Sure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do you know any adults who work as scientists?</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Do you know any adults who work as engineers?</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Do you know any adults who work as mathematicians?</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Do you know any adults who work as technologists?</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>
### APPENDIX G: STUDENT INTERVIEW QUESTIONS

#### Semi-Structured Interview Questions – First Interview

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>How do you feel when you’re learning science?</td>
<td></td>
</tr>
<tr>
<td>Do you think that you’re good at science?</td>
<td></td>
</tr>
<tr>
<td>Do you think that you can teach others science?</td>
<td></td>
</tr>
<tr>
<td>How do you feel about the following statement:</td>
<td></td>
</tr>
<tr>
<td>I could be an engineer someday.</td>
<td></td>
</tr>
<tr>
<td>What do you like about science? What do you not like about science?</td>
<td></td>
</tr>
<tr>
<td>Do you think that science and engineering are important?</td>
<td></td>
</tr>
<tr>
<td>What do you think you want to be when you grow up?</td>
<td></td>
</tr>
</tbody>
</table>

#### Semi-Structured Interview Questions – Second Interview

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>How do you feel when you’re learning science?</td>
<td></td>
</tr>
<tr>
<td>Do you think that you’re good at science?</td>
<td></td>
</tr>
<tr>
<td>How do you feel about the following statement:</td>
<td></td>
</tr>
<tr>
<td>I could be an engineer someday.</td>
<td></td>
</tr>
<tr>
<td>Do you think that science and engineering are important?</td>
<td></td>
</tr>
<tr>
<td>What do you think you want to be when you grow up?</td>
<td></td>
</tr>
<tr>
<td>How did the engineering design process help you to understand what you were learning about in science?</td>
<td></td>
</tr>
<tr>
<td>How did using the engineering design process help you feel like an engineer?</td>
<td></td>
</tr>
<tr>
<td>Explain a time that you felt most proud of your work (or felt that you were the most capable of doing your work) during a design process activity.</td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX H: IRB APPROVAL

UNIVERSITY OF SOUTH CAROLINA

OFFICE OF RESEARCH COMPLIANCE

INSTITUTIONAL REVIEW BOARD FOR HUMAN RESEARCH
APPROVAL LETTER for EXEMPT REVIEW

Whitney Oberndorf
820 Main Street
Columbia, SC 29208

Re: Pro00126648

Dear Mrs. Whitney Oberndorf:

This is to certify that the research study Impact of the Engineering Design Process on Rural Female Students’ Achievement and Self-Efficacy was reviewed in accordance with 45 CFR 46.104(d)(1), the study received an exemption from Human Research Subject Regulations on 2/7/2023. No further action or Institutional Review Board (IRB) oversight is required, as long as the study remains the same. However, the Principal Investigator must inform the Office of Research Compliance of any changes in procedures involving human subjects. Changes to the current research study could result in a reclassification of the study and further review by the IRB.

Because this study was determined to be exempt from further IRB oversight, consent document(s), if applicable, are not stamped with an expiration date.

All research related records are to be retained for at least three (3) years after termination of the study.

The Office of Research Compliance is an administrative office that supports the University of South Carolina Institutional Review Board (USC-IRB). If you have questions, contact Lisa Johnson at lisaj@mailbox.sc.edu or (803) 777-6670.

Sincerely,

Lisa M. Johnson
ORC Assistant Director and IRB Manager