ENHANCING STUDENTS' ENGINEERING IDENTITIES AND ATTITUDES TOWARDS ENGINEERING AND TECHNOLOGY THROUGH PLACE-CONSCIOUS ENGINEERING ACTIVITIES

by

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A thesis submitted in partial fulfillment
of the requirements for the degree

of

Master of Education

in

Curriculum and Instruction

MONTANA STATE UNIVERSITY
Bozeman, Montana

January 2024

ACKNOWLEDGEMENTS

This study used data from the Looks Like Me (LLM) project. The LLM is a large National Science Foundation-funded project (award number 1916673) focusing on leveraging rural and reservation students' funds of identity to bolster engineering career pursuits. I sincerely thank the entire LLM project team for their pivotal role in this achievement. Special thanks go to my advisor, Dr. Rebekah Hammack, the principal investigator of the LLM project, for granting me the rare privilege of working with the LLM project.

From the onset of my master's program to completing this thesis, Dr. Rebekah Hammack mentored me - guiding me in conducting research, offering constructive feedback on my writing, pointing me to essential academic resources, and helping me navigate graduate school. I am also deeply grateful to Dr. Nick Lux, who stepped in as co-chair following Dr. Rebekah Hammack's departure from Montana State University. Dr. Nick Lux and Dr. Rebekah Hammack read my thesis drafts several times and collaboratively provided valuable feedback that helped me shape this thesis. I also want to thank Dr. Paul Gannon for serving on my committee and providing insights that helped develop this thesis. To the entire LLM project team, thank you for being my pillars of strength and for playing an integral role in completing my graduate studies.

Finally, I extend my gratitude to my family and friends for their unwavering emotional support throughout this rigorous academic journey. Their encouragement and consistent check-ins on my well-being were invaluable as they helped me persist in completing this graduate program. I greatly appreciate their understanding and patience when I was unavailable due to busy schedules. This reinforced the importance I attached to achieving this milestone and helped me work towards completing my graduate program.

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ABSTRACT

Students' engineering identities and attitudes toward engineering are important because they can determine if students will pursue engineering careers. However, a dearth of research focuses on how participating in place-conscious engineering affects students' engineering identities and attitudes towards engineering and technology. This explanatory sequential mixed methods study investigated the effect of engaging elementary students in place-conscious engineering activities on their engineering identities and attitudes towards engineering and technology. Students completed two place-conscious engineering activities: (1) following a local wildfire, students designed and built air filters to prevent smoke from entering the homes of affected families residing in a nearby community, and (2) after the state issued several warnings about eminent floods due to ice-jams on a local river, students designed flood prevention strategies. Quantitative data about students' engineering identities were collected using pre and post surveys of the two subscales of the Engineering Identity Development Scale (EIDS): (1) academic subscale and (2) engineering career subscale. Quantitative data regarding students' attitudes toward engineering and technology were collected using pre and post surveys of the engineering and technology subscale of the Students' Attitudes Toward Science, Technology, Engineering, and Mathematics (S-STEM). Finally, to explain the trends observed in the quantitative data, qualitative data were collected through semi-structured focus group interviews. Findings suggested that students' academic identities and attitudes towards engineering and technology improved as a result of participating in place-conscious engineering activities. The study recommends exposing elementary students to place-conscious engineering activities to improve their engineering identities and attitudes towards engineering and technology.

CHAPTER ONE

INTRODUCTION

Background

The US relies on Science, Technology, Engineering, and Mathematics (STEM) to boost its national security, foster economic growth, and drive the nation's advancements through the development of innovative ideas (Lyons & Thompson, 2006; Noonan, 2017). Thus, The President's Council of Advisors on Science and Technology (2010) has continued to emphasize the significance of STEM in the United States. Learning STEM is associated with increased logical thinking and critical reasoning (Sadler & Zeidler, 2005). Skills learned through engaging with STEM are valuable for all citizens because they are transferrable and can apply to a variety of contexts (Marrero et al., 2014). All citizens need STEM knowledge to comprehend and handle challenges from personal to global viewpoints (Bybee, 2010). A basic understanding of STEM allows individuals to make informed decisions for themselves, their families, and their communities (Tate et al., 2012), including decisions related to: personal health, energy efficiency, environmental quality, resource use, economics, politics, cultural values, and national security (Bybee, 2010). Students who receive robust STEM education are better prepared to address 21st-century sustainability concerns such as health, climate change, and access to fresh water (Johnson, 2012). Therefore, it is crucial that every person has access to STEM education (Marrero et al., 2014).

The US's commitment to improving STEM education is evident in the recent educational reforms initiated by the National Research Council [NRC] (2012) through the publication of the

Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas. The framework proposed the development of new science standards, the Next Generation Science Standards (NGSS) (NGSS Lead States, 2013; NRC, 2012). Among the changes introduced by the NGSS are (1) three-dimensional learning, which integrates disciplinary core ideas, crosscutting concepts, and science and engineering practices; (2) integration of engineering design process skills within science education; and (3) integration of the use of technology into science education for collecting and analyzing data and communicating (NGSS Lead States, 2013). Today, 24 states and the District of Columbia have adopted the NGSS, and 20 states have created their own standards based on the NGSS (Carnegie Corporation of New York, 2021). These states and the District of Columbia account for over 70% of US students who now either use the NGSS or similar standards, which among other things, require them to learn and develop competence in engineering and technology. Thus, the emergence of the NGSS has fueled an increased focus on engineering education research (Kittur & Brunhaver, 2020).

However, in academic and professional settings, there is still a problem with recruiting and retaining engineers (Hanover Research, 2014; Patrick & Borrego, 2016). Also, there has been a lack of gender and racial/ethnic diversity in college engineering programs and the engineering workforce (Chubin et al., 2005; Faulkner, 2009). Many engineering students switch from engineering to other degrees due to a lack of identification with engineering (Patrick & Borrego, 2016). Attrition rates are relatively higher for STEM majors than other majors (Rask, 2010) with less than 40% of students entering college to major in a STEM field completing a STEM degree (Olson & Riordan, 2012). Few students pursue STEM degrees (Cannady et al., 2014), and few of those with STEM degrees choose to take up STEM jobs (Lichtenstein et al., 2009). For example, a survey of 80 senior engineering majors from two US universities found that only 42% confirmed their intention to pursue a career in engineering, 44% were uncertain regarding it, and 14% reported disinterest in pursuing a career in engineering (Lichtenstein et al., 2009). This study and others highlight that the number of students choosing engineering careers has been declining in the US (Tonso, 2006). Many STEM jobs remain vacant due to a shortage of qualified persons (Atkinson, 2013), resulting in a high demand for skilled STEM workers (Zheng, 2022) and pressure to increase the number of scientists and engineers in the US (Avery & Kassam, 2011).

There are disparities in STEM education research across different levels of education - elementary, middle, high school, and college (Carter, 2020). Much of the research on student retention in STEM is focused on adults or the high school and college levels (Belser et al., 2017; Bowling et al., 2013; Cromley et al., 2016; Dika & D'Amico, 2016; Lichtenstein et al., 2009). Such studies highlight the importance of addressing student retention in STEM at the adult and higher education levels. Similarly, more than fifty percent of federal funding for STEM education is designated to cater to the needs of postsecondary institutions and their students, while the remainder is allocated to initiatives aimed at improving STEM education at the K-12 level (Granovskiy, 2018). Much STEM education research concentrates on high school levels while there is comparatively less STEM education research at the elementary and middle school levels (Carter, 2020; Gossen et al., 2021). This is also true for research specifically focused on elementary students' interests in STEM, yet students' STEM interests develop early in their lives (Gossen et al., 2021).

Research shows that children are born with the curiosity that many engineers possess and have a natural inclination towards problem-solving but traditional education tends to suppress this aspect (Hu, 2010). Children engage with engineering informally from a young age (Hester & Cunningham, 2007), and their attitudes towards science and mathematics usually develop during their elementary school years (Lyons & Thompson, 2006). However, their interest in science and engineering tends to decrease during middle school (Christidou, 2011; Lindahl, 2007). Research has repeatedly shown that the middle school years play a crucial role in shaping one's future career goals (Blackhurst & Auger, 2008). The elementary and middle school are vital stages for educators to design and implement strategies that leverage students' natural engineering inclination. Matusovich et al. (2021) stress that if students are not equipped, made aware of, and interested in engineering at an early age, they risk losing their chances of becoming engineers. Conrad et al. (2018) found that if students are exposed to engineering early in their school years, they are more likely to pursue it as a career (Selingo, 2007). Therefore, there is a need for conducting STEM education research focusing on elementary and middle school levels.

Research shows that students' early exposure to STEM projects and activities has favorable effects on elementary students' attitudes towards and perceptions of STEM (DeJarnette, 2012). In turn, students' attitudes towards disciplines influence students' career choices (Guzey et al., 2014; Maltese & Tai, 2011; Tseng et al., 2013). Hammack and Ivey (2019) and English et al. (2011) emphasize the significance of introducing students to STEM activities and careers during their elementary school years. Teachers must tap into young students' engineering potential (Lightner et al., 2021) as the long-term success for American education may depend on exposing even the youngest students to STEM subjects (DeJarnette, 2012).

Research has linked students' low participation in STEM careers to a lack of access to STEM extracurricular activities and advanced courses (Saw & Agger, 2021). Therefore, some scholars stress the need to expose students to engineering and technology learning opportunities (National Academies of Sciences, 2020, 2021). Previous research suggests that students' prolonged engagement in design and engineering activities can improve confidence in completing engineering-related tasks (Bleicher & Lindgren, 2005; Hechter, 2011; Rich et al., 2017; Tosun, 2000). Other scholars stress the need for increasing students' engineering identity (Godwin, 2016; Meyers et al., 2012) and attitudes towards STEM (Guzey et al., 2014; Maltese & Tai, 2011) as factors that could consequently increase their persistence in learning engineering and their likelihood to pursue engineering careers. Also, research suggests that students' engagement in place-based STEM activities connects classroom STEM to students' local environments and thus promotes the growth of their attitudes towards STEM (Buxton, 2010; Johnson et al., 2009). Therefore, students' growth of engineering identities and attitudes toward STEM may positively impact their persistence in pursuing STEM careers. However, there is a dearth of research focusing on understanding the relationship between engaging elementary students in place-conscious engineering activities and developing their engineering identities and attitudes toward engineering and technology.Statement of Problem

Engineering and technology are interwoven in many aspects of human life and hence play an essential role in the welfare of many Americans (National Research Council [NRC], 2012; Novak & Wisdom, 2018). Engaging in STEM education allows students to acquire 21st-century skills and prepare them to become citizens who can make sound decisions about their own health, energy efficiency, environmental quality, resource usage, and national security

(Bybee, 2010). Education in STEM-related fields can also help individuals to secure well-paying jobs (Morrison et al., 2009). Therefore, every student needs access to high-quality engineering and technology education (National Academies of Sciences, 2020, 2021). However, some students have little access to high-quality engineering and technology education, which is one of the reasons they may not pursue engineering and technology careers (National Academies of Sciences, 2020). Many studies show that students' engineering identities and attitudes towards STEM are vital factors that influence students' career choices. Students with positive engineering identities and attitudes towards STEM are more likely to pursue engineering careers than their counterparts with negative engineering identities (Maltese & Tai, 2011; Meyers et al., 2012; Morelock, 2017). However, there is a limited understanding of how exposing elementary students to place-conscious engineering activities influences the development of their engineering identities and attitudes towards engineering and technology, particularly in the context of Montana.

Purpose of the Study

This sequential explanatory mixed methods study explored the effects of engaging elementary students in place-conscious engineering activities on the development of their engineering identities and attitudes towards engineering and technology. Specifically, the research questions included:

1. What is the impact of engaging elementary students in place-conscious engineering activities on their engineering identities?

2. What is the impact of engaging elementary students in place-conscious engineering activities on their attitudes towards engineering and technology?

3. What do students' descriptions of their engagement with engineering activities reveal about their engineering identities and attitudes towards engineering and technology?

4. How do the findings from the qualitative interview support the findings from the quantitative survey?

Hypothesis

Two research hypotheses guided the quantitative piece of this investigation. The first and second hypotheses were linked to the first and second research questions respectively.

1. There is a statistically significant increase in students’ engineering identities after engaging in place-conscious engineering activities.
2. There is a statistically significant increase in students’ attitudes towards engineering and technology after engaging in place-conscious engineering activities.

Significance of the Study

The findings from the present study provided important information about elementary students’ development of engineering identities and attitudes towards engineering and technology when exposed to multiple place-conscious engineering activities. This will provide researchers with information about leveraging place-conscious engineering activities to influence students’ development of engineering identities and attitudes towards engineering and technology. Aside from that, research in engineering education (Dart et al., 2021), especially engineering identity development (Capobianco et al., 2012; Patrick & Prybutok, 2018) is still growing in the US. Therefore, this study can potentially influence the focus of future research related to students' engineering identity development and/or attitudes toward engineering and technology. Equally important, students' lack of identification with (Meyers et al., 2012; Morelock, 2017; Patrick & Prybutok, 2018) and negative attitudes towards (Guzey et al., 2014; Maltese & Tai, 2011) engineering have been linked to students' low persistence in pursuing engineering careers. Therefore, by studying how elementary students develop their engineering identities and attitudes towards engineering and technology, the present study contributed to existing efforts targeted at promoting students' access to and participation in science and engineering.

Operational Definitions

This study used the following operational definitions to help readers understand the contextual meaning of essential terms used throughout this document.

1. Place-conscious engineering activities – students' classroom engineering activities that consider cultural, social, economic, and political aspects within students' environment (Elfer, 2011).
2. Attitudes – students' feelings and beliefs toward engineering and technology (Cherry, 2022).
3. Engineering Identity - Students' sense of belonging, connection, and commitment to academic identity and engineering aspirations (Capobianco et al., 2012).

4. Collaboration - Working together or completing a shared task to achieve a common engineering goal, leveraging their diverse perspectives, knowledge, and skills.
5. Engineering design - An iterative decision-making and problem-solving process undertaken as part of a broader engineering goal, often involving testing and improving engineering designs to meet specific requirements.
6. STEM education – formal and informal teaching and learning of science, technology, engineering, and mathematics at pre-college and college levels (Granovskiy, 2018).

Chapter Summary

This chapter explored the importance of engineering to students, citizens, and the nation. It also highlighted America's commitment to improving engineering education - citing how the recent introduction of the NGSS into state and national standards requires the incorporation of engineering within K-12 science curricula. The chapter went further to identify challenges in recruiting and retaining engineers in academic and professional settings and identifies identity and attitudes as important constructs that could influence students' persistence in learning engineering. Finally, it discussed the lack of understanding of the relationship between students' participation in place-conscious engineering activities and students' engineering identities and attitudes as the study problem. The next chapter provides an in-depth analysis of relevant literature, focusing on three major themes: (1) engineering identity, (2) the role of attitude in learning, and (3) the role of place in learning. The study methods, results, and discussion are discussed in chapters 3, 4, and 5, respectively.

CHAPTER TWO

LITERATURE REVIEW

Introduction

This chapter provides an extensive review of the literature relevant to this study. The chapter focuses on three major areas of literature: (1) engineering identity, (2) the role of attitude in learning, and (3) the role of place in learning. The researcher further explores how these interrelated constructs connect to social cognitive career theory (SCCT) as the theoretical framework guiding this study.

Engineering Identity

Brickhouse et al. (2000) underscore the importance of identity in encouraging students to pursue science and engineering programs and careers. Engineering identity has provided researchers with a relatively new lens for studying students' persistence and retention in learning engineering (Patrick & Prybutok, 2018). Over the past two decades, the importance of engineering identity within educational research has increased (N. Li et al., 2021; Rodriguez et al., 2018). The number of researchers focusing on identity theories as a framework to better understand students' persistence in learning STEM subjects is increasing (Patrick & Prybutok, 2018).

Despite research in engineering identity growing, it is still underdeveloped (Capobianco et al., 2012). Engineering identity is less theorized than science and math identities (Patrick & Prybutok, 2018). A systematic literature review by Rodriguez et al. (2018) found that a greater number of studies integrate engineering identity with existing well-established theories such as motivation (i.e., desire to achieve goals) and choice (i.e., career choice) rather than creating new theoretical frameworks. These studies draw from fields such as psychology, sociology, and education (Morelock, 2017; Rodriguez et al., 2019). The limited number of studies building new engineering identity theoretical frameworks could further indicate that research focused on engineering identity is still underdeveloped. Another observation is that many studies focusing on engineering identity treat engineering identity as a predictor of other variables, such as engineering career interest (Cribbs et al., 2016; Godwin et al., 2013; Sheppard et al., 2010), while few treat engineering identity as an outcome of other variables (Meyers et al., 2012). Finally, limited research focuses on elementary students' engineering identity formation when compared to high school and college students (Capobianco et al., 2017). Studying how elementary students "approach, experience, and interact" with engineering activities could help explain factors that boost or suppress engineering identity formation (Capobianco et al., 2017, p. 45).

Engineering education and engineering identity are intertwined and thus inseparable (Eliot & Turns, 2011; Tonso, 2006; Tonso, 2014). Studies show that engineering identity is a significant indicator of educational and professional persistence (Campbell, 2007; Capobianco et al., 2012; Chachra et al., 2008; Du, 2006; Jorgenson, 2002; Meyers et al., 2012; Tonso, 2006). Tonso (2007) defines identity as a sense of belonging and views students' sense of belonging to the engineering community as vital in informing their academic and professional persistence (Meyers et al., 2012). Students who identify as engineers are more likely to persist in engineering programs than those who do not (Pierrakos et al., 2009). Engineering identity is also essential for supporting students' academic and personal development (Jocuns et al., 2008; Matusovich et al., 2010), retention in engineering programs (Godwin & Potvin, 2015; Walden & Foor, 2008), and assimilation into the larger engineering community (Downey & Lucena, 2003; Tonso, 2006; Tonso, 2006b). Existing research associates engineering identity with favorable students' outcomes such as students' academic success (Eliot & Turns, 2011; Tonso, 2014), engagement in learning (Pierrakos et al., 2009), and intentions to take up engineering careers (Godwin et al., 2013). The importance of students having strong engineering identities is also evident in the number of students who, despite having the potential to become engineers, leave the engineering pipeline due to a lack of identification with engineering (Ong et al., 2011; Patrick & Borrego, 2016; Pierrakos et al., 2009; Ross & Godwin, 2016). A lack of identification with engineering is partly responsible for students switching majors from engineering to other majors and can be a barrier to students looking to switch from other majors to engineering (Seymour & Hewitt, 1997; Tonso, 2006).

If students are to pursue science and engineering, they must see themselves as the "kind of people who would want to understand the world scientifically" (Brickhouse et al., 2000, p. 443). Developing positive engineering identities requires students to envision themselves as engineers and be recognized by others as engineers (Rodriguez et al., 2018). Engineering identity formation requires students to negotiate their responsibilities within engineering as a discipline, among their peers, and in their classrooms (Godwin, 2016). Teachers must recognize and act upon students' engineering identities to provide them with favorable engineering learning environments (Tonso, 1997; Tonso, 2006).

Identity is complex as it can be viewed from different perspectives (Capobianco et al., 2012). Burke et al. (2003) stress the importance of recognizing the complex interplay between various aspects of identity. Prior studies on engineering identity draw from different theories, such as the multiple identity theory (Capobianco et al., 2012; Matusovich et al., 2011), identity stage theory (Godwin & Potvin, 2015; Meyers et al., 2012; Min et al., 2011), communities of practice (Pierrakos et al., 2009; Stevens et al., 2008), and figured worlds (Tonso, 2006). Framing engineering identity from different perspectives reflects its complexity, diversity, and inclusiveness (N. Li et al., 2021). A systematic literature review by Morelock (2017) identified four distinct approaches to defining or operationalizing engineering identity: (1) identity as a combination of other facets of identity, specifically the quadripartite view developed by Gee (2000), which includes nature-identity, institution-identity, discourse-identity, and affinity-identity; (2) identity as an individual's self-perceptions in relation to engineering and how other people perceive an individual; (3) identity as a construct involving analyzing cognitive factors (i.e., competence), affective factors (i.e., task value), and performance factors (i.e., academic achievement); and (4) identity as a result of an individual's specific action.

<u>Engineering Identity and the Stage Theory</u>

Stage theory is grounded in developmental psychology and is a foundation for many developmental theories such as Jean Piaget's Theory of Cognitive Development and Erik Erikson's Psychosexual Stages of Development. According to Meyers et al. (2012), the stage theory is based on the premise that (1) each developmental stage has unique characteristics, and the stages follow a universal sequence; (2) the progression rate from stage to stage and the final stage accomplished differs from individual to individual; and (3) progression from one stage to another is gradual. "Identity is not a static object but a creative process… humans create, construct, work on, and enact their identities" (Kondo, 1990, p. 48). Identity constantly transforms and adapts to various influences, including societal norms, but at the same time, remains resilient and persists over time and situations (Hernandez-Matias et al., 2020). Based on the dynamic nature of engineering identity, Meyers et al. (2012) modeled identity development using the stage theory. Several studies have found that undergraduate students majoring in engineering better understand what it means to identify with engineering as they progress from their first year to their senior year (Meyers et al., 2012; Stevens et al., 2008; Tonso, 2007). The fact that identity can be changed means that with the right interventions, educators can influence positive change in students' engineering identities.

<u>Identity as Personal, Social, and Academic</u>

Some scholars consider different kinds of identity as intricately interconnected and interacting. For example, personal and social identities influence students' development of their academic identities (i.e., engineering identity) (Hazari et al., 2010). Thus, some STEM educators define identity by integrating multiple other identities, such as personal, social, and academic identities (Chemers et al., 2011).

<u>Personal Identity.</u> Personal identity is an individual's self-defining characteristics and experiences (Kendall et al., 2019). It refers to the self-categorizations that distinguish an individual as a distinct person, highlighting their unique qualities and distinguishing them from others within their social group (Turner et al., 1992). Hazari et al. (2010) add that personal identity is highly individual and centers on self-defining characteristics such as "I am caring", "I am contentious, etc."

<u>Social Identity.</u> Social identity is an individual's identity as a social group member (Deaux, 1994; Kendall et al., 2019; Turner et al., 1992). While personal identity can be

idiosyncratic, social identity considers the commonalities individuals share with others within a social group (Deaux, 1994). There are many kinds of social identities with common examples including ethnic and religious identities (i.e., African, American, Jewish, Christian), political identities (i.e., feminist, republican, democrat, environmentalist), vocations and avocations (i.e., engineer, scientist, psychologist, artist, athlete), personal relationships (i.e., parent, wife, teenager, widow), and stigmatized groups (i.e., person with AIDS, people living in poverty, disabled people, alcoholics) (Deaux, 1994).

<u>Academic Identity.</u> Academic identity, also known as context and role-oriented identity, is an individual's identity within a specific community of practice (i.e., in engineering) (Hazari et al., 2010). This kind of identity is affected by expectations and perceptions associated with a particular community of practice (Hazari et al., 2010). An example of a statement individuals could make pertaining to academic identity include, "I am an engineering person" (Hazari et al., 2010). In studying academic identities such as engineering identity, it is crucial to acknowledge the importance of other kinds of identities such as personal and social identities because they interact and influence engineering identity development (Hazari et al., 2010). For example, consider an individual whose personal identity encompasses their gender as female and their social identity as a member of an ethnic group whose traditional practices disapprove exploiting nature as part of engineering. The rarity of female representation in engineering and potential conflicts between their traditional practices and certain aspects of the engineering field could undermine their engineering identity.

Identity as Performance/Competency, Recognition, and Interest

Carlone and Johnson (2007) developed a theoretical framework that views identity as a combination of performance, competency, and recognition. Hazari et al. (2010) expanded this framework by adding a fourth component, interest, and combined performance and competence (i.e., performance/competence) after discovering that they loaded to the same factor. Hazari et al.’s (2010) framework posits that an individual's performance/competency, recognition, and interest in a discipline (i.e., engineering) influence their identity. In two separate studies, Godwin et al. (2013) and Prybutok et al. (2016) found that Hazari et al.’s (2010) framework worked well. Patrick and Prybutok (2018) performed a logistic regression to predict students’ engineering identity and found that Hazari et al.’s (2010) three components were significant predictors of students’ engineering identity. They found that students with these three components showed the strongest engineering identities (Patrick & Prybutok, 2018). Kendall et al. (2019) also found that these three components plus three others (analysis, framing and solving problems, and tinkering) were significant predictors of students’ engineering identities. Carlone and Johnson’s (2007) and Hazari et al.’s (2010) frameworks have been used by several studies focusing on students’ engineering identities (Godwin, 2016; Godwin & Potvin, 2017; Godwin et al., 2016b; Hazari et al., 2010; Kendall et al., 2019; Patrick & Prybutok, 2018). The following sections explore the three components of Hazari et al.’s (2010) framework in greater detail.

Performance/competence. Performance refers to a student's confidence in their capacity to succeed when carrying out engineering tasks (Patrick & Prybutok, 2018). Students who perform poorly in class are not likely to identify as engineers and vice versa (Patrick & Prybutok, 2018). As students transition from novices to experts, their identities change, and participating more fully in the community of practice becomes an integral part of their learning (Tonso, 2015).

Competence refers to students' belief in their ability to understand engineering concepts (Patrick & Prybutok, 2018). Students’ competency beliefs in engineering influence their engineering identity formation and engineering career choices (Godwin, 2016; Hazari et al., 2010). In addition, students’ beliefs about their abilities to complete engineering practices play a role in shaping their self-perceptions as individuals who can legitimately participate in engineering (Godwin, 2016). Both performance and competence influence students’ engineering identity as they connect to students' sense of belonging and preparedness to succeed in learning engineering (Patrick & Prybutok, 2018). Also, engaging in hands-on learning experiences can promote individuals’ acquisition of knowledge and skills and, in turn, their performance and competence (Hernandez-Matias et al., 2020).

Recognition. Recognition is a significant factor in determining an individual’s engineering identity (Godwin, 2016; Godwin et al., 2014; Hazari et al., 2010; Huttunen & Heikkinen, 2004; Rodriguez et al., 2018). When students receive recognition from their peers, parents, and teachers as legitimate group members in engineering, their engineering identity development is enhanced (Godwin, 2016; Wenger, 1999) and they tend to behave in a manner that supports their continued recognition (Carlone & Johnson, 2007). The influence of recognition on identity is evident in Tonso (1999, 2006), who found that students who demonstrated excellent engineering skills but lacked recognition from their peers showed weaker engineering identities and a poor sense of belonging to engineering.

Interest. Interest is a "person's likes, preferences, favorites, affinity toward, or attraction to a subject, topic, or activity" (Dunst & Raab, 2011, p. 11). Patrick and Prybutok (2018) describe interest as students' motivation in a particular content area (i.e., completing engineering tasks). Interests usually encompass pleasure, fulfillment, and emotional connection to a task or activity (Dunst & Raab, 2011). Interest accounts for reasons students identify with and persist in learning to engineer; it influences students' decision to take on role-identity as engineers or not (Godwin, 2016; Hazari et al., 2010).

Hazari's framework posits that improving students' performance/competence, recognition, and interest results in a corresponding improvement in their engineering identities. Teachers must provide students with multiple opportunities to: develop their performance/competence, gain recognition from their peers and teachers, and elicit interest in engineering. This intervention is especially important at early stages because students begin to develop identities upon entering a community of practice (i.e., elementary engineering) and engaging in engineering tasks (Capobianco et al., 2017).

Enhancing Engineering Identities through Hands-on Engineering Activities

Some scholars have found that elementary students' participation in hands-on engineering activities significantly improves their engineering identities (Capobianco et al., 2017; Douglas et al., 2014; McLean et al., 2020). For example, Douglas et al. (2014) engaged 818 elementary school students in a year-long engineering curriculum incorporating hands-on engineering design activities to explore what engineering is about. The study found that students' engineering identities significantly improved from pre to post, suggesting that engagement in hands-on engineering design activities improves students' engineering identities.

While Douglas et al. (2014) merely focused their intervention on engaging students in hands-on engineering design activities, more recent studies such as McLean et al. (2020) and Capobianco et al. (2017) creatively tied students' engineering design activities to authentic engineering contexts and found such interventions equally effective. McLean et al. (2020) conducted a qualitative study to assess the impact of engaging elementary students (n=11) in collaborative engineering-design activities on students' engineering identities. Elementary students worked in small groups to design and build dancing robots that would later be brought together for a coordinated dance performance. Consistent with how real-world engineers work, students iteratively sketched and improved their dancing robot designs before building them. Findings showed that students' engagement in collaborative authentic engineering design activities encouraged students to engage in and identify with engineering. Capobianco et al. (2017) examined 200 elementary students' engineering identity formation before and after engaging them in a year-long science instruction incorporating engineering design activities. With specific requirements by a client and constraints similar to those faced by real-world engineers, students designed musical instruments, door alarms, water canals, and roller coasters. Findings show that students' understanding of engineering concepts, the engineering profession, and the work of engineers improved. Most importantly, students' engineering identities and engineering career aspirations improved because of their engagement in authentic engineering design activities.

The aforementioned studies (Capobianco et al., 2017; Douglas et al., 2014; McLean et al., 2020) each administered similar interventions to students within the same grade-band and found similar results. Collectively, these studies provide evidence that students' participation in hands-on engineering design activities could potentially improve students' engineering identities. Compared to Douglas et al. (2014), McLean et al. (2020) and Capobianco et al. (2017) took students' engineering design an extra step by specifically framing these activities to mimic real-world engineering practices, such as working within set constraints and iteratively improving engineering designs, which may also help students better understand the work of engineers. Despite these studies approaching students' engineering design activities differently, they reached identical conclusions, providing evidence that hands-on engineering design activities positively influence students' engineering identities.

The Role of Attitude in Learning

Cherry (2022) describes an attitude as a combination of feelings, beliefs, and actions toward a specific object, person, or event. According to Ajzen (2001), attitude is a summary evaluation of psychological objects perceived as "good-bad, harmful-beneficial, pleasant-unpleasant, and likable-dislikable" (p. 28). McConnel (1980) views attitudes as a style of thinking, feeling, and behaving towards objects, people, ideas, or events. Often, individuals' attitudes involve their emotional feelings or biases, which influence them to act in certain ways (McConnel, 1980; Olufemi, 2012). Research shows that attitudes consist of three major components: (1) cognitive – an individual's thoughts and beliefs about something; (2) affective – how an individual feels about a person, issue, or event; and (3) behavior – how an individual's attitude influences behavior (Cherry, 2022; Lolliot et al., 2015; Olufemi, 2012; Pickens, 2005;

Svenningsson et al., 2022). In addition, many factors influence individuals' attitudes, including (a) past experiences; (b) social factors such as norms and values of society; (c) learning of new knowledge; (d) operant conditioning; and (e) observing other people's attitudes (Cherry, 2022).

Individuals' attitudes can significantly impact their actions and behaviors in different situations (Cherry, 2022; McConnel, 1980). Individuals are more inclined to do things they have positive attitudes towards than those they have negative attitudes towards (Olufemi, 2012). Individuals' attitudes towards, for example, engineers are influenced by their beliefs about engineering, which can in turn, influence their behaviors towards engineering (Svenningsson et al., 2022). Research shows that while individuals' attitudes can be enduring, they are not fixed but can change over time as individuals acquire new knowledge (Cherry, 2022; McConnel, 1980; Olufemi, 2012; Pickens, 2005; Reeve et al., 2015). This flexibility allows educators to seek and implement interventions that help students develop positive attitudes towards learning subjects such as engineering.

Investigating students' attitudes is essential because attitude influences students' behaviors (Pickens, 2005; Svenningsson et al., 2022). In educational settings, students' attitudes towards disciplines have been shown to influence students' career choices (Guzey et al., 2014; Hirsch et al., 2007; Maltese & Tai, 2011; Tseng et al., 2013). Therefore, it is not surprising that researchers often use students' attitudes as a proxy for assessing students' knowledge and willingness to pursue certain careers (Svenningsson et al., 2022). This, together with the consideration that strong attitudes tend to be relatively resistant to change (Ajzen, 2001), highlights why teachers should help their students develop strong positive attitudes towards engineering.

<u>Importance of Attitude</u>

According to Social Cognitive Career Theory, individuals' career choices partly depend on their interests, attitudes, and values (Lent et al., 1994). Encouraging more students to choose engineering to meet the national demand requires students to develop positive attitudes toward engineering (Brevik et al., 2014). Students' attitudes towards engineering can affect their (1) achievement, persistence, and retention in engineering programs; (2) engineering self-efficacy; and (3) perceptions of and motivation for learning engineering (Besterfield-Sacre et al., 1998; Gasiewski et al., 2012).

While some scholars point to students' grades as determinants of students' retention in engineering programs (Alkhasawneh & Hargraves, 2014; Mendez et al., 2008; Reason, 2003), they do not fully account for why students leave engineering programs (Besterfield-Sacre et al. (1997). Some researchers have found that attitude predicts students' academic success better than academic abilities (Steiner & Sullivan, 1984). For example, Besterfield-Sacre et al. (1997) found that students who left engineering programs in good academic standing had similar grades as those who persisted. However, the students who left had poorer attitudes towards engineering. Those who left had low impressions of engineers and their work and did not value engineers' work (Besterfield-Sacre et al., 1997). Even students who are adequately prepared to pursue engineering leave engineering programs because of their poor attitudes towards engineering (Hirsch et al., 2003). To support students' persistence in learning engineering, improving students' attitudes toward engineering is as important as improving their engineering competence (PCAST, 2010). In fact, research shows that students' attitudes towards engineering predict their likelihood of pursuing engineering careers (Hirsch et al., 2007). Educational researchers should focus on improving students' attitudes towards engineering to increase their retention in engineering programs (Unfried et al., 2015). This is crucial, considering that research on students' attitudes towards engineering is still sparse (Hammack et al., 2015; Lyons et al., 2009; Suprapto, 2016).

Research in engineering education is growing (Dart et al., 2021), and research focusing on students' attitudes towards engineering and technology is gaining ground (Guzey et al., 2014). However, more research focuses on students' attitudes towards science (Lyons et al., 2009; Osborne et al., 2003) and mathematics (Ozgun-Koca & Sen, 2011) than attitudes towards engineering and technology (Hammack et al., 2015; Lyons et al., 2009; Suprapto, 2016). Research on students' attitudes towards engineering and technology at the middle school level is limited (Hammack et al., 2015). However, the elementary and middle school are crucial years for developing students' attitudes towards engineering and technology because students tend to make career choices during this time (Gibson, 2005; Guzey et al., 2014). This further highlights a need for increased research on students’ attitudes towards engineering at the elementary and middle school levels.

Pickens (2005) asserts that attitude is highly related to perception and positions perception as an important construct in discussing attitude. According to the field of psychology, perception refers to individuals’ sensory encounters with the world, involving their recognition and interpretation of sensory information (Leung & Levitas, 2022). On the other hand, attitude is more holistic in that it also encompasses individuals’ opinions, beliefs, feelings, and behaviors (Pickens, 2005). Research has repeatedly shown that students hold negative perceptions of engineers, which could hinder them from pursuing engineering careers (Hammack et al., 2015).

Some K-12 students lack an understanding of what engineers do (Hammack et al., 2015; Hirsch et al., 2003), hold negative perceptions of engineers (Hammack et al., 2015), and have little interest in STEM fields (Roller et al., 2018). They perceive engineers as nerds, less family-orientated people, and think that to become an engineer, they must be geniuses (Hirsch et al., 2003). Changing students' negative perceptions and attitudes towards engineers requires employing innovative interventions such as increasing students' opportunities for personal experiences with engineering and interacting with real-world engineers to provide students with vicarious experiences (Olufemi, 2012).

Improving Students' Attitudes Towards Engineering

Individuals' attitudes are relatively stable but can change over time (McConnel, 1980; Olufemi, 2012). This flexibility allows educators to plan and implement interventions to influence students' attitudes towards engineering and other related disciplines. Researchers have linked students' increased attitudes towards engineering-related disciplines to several factors, including students' engagement in authentic hands-on engineering learning experiences. For example, Cunningham and Lachapelle (2010) engaged 1056 elementary students from six states in an Engineering is Elementary (EiE) program involving creating, evaluation, and improving engineering designs. Findings show that the EiE curriculum positively affected students' understanding of engineering concepts, the work of engineers, the role of engineering in society, and attitudes towards engineering.

While Cunningham and Lachapelle (2010) focused their intervention on elementary students, studies at the middle and high school levels found similar results, suggesting that students' engagement in engineering-design activities can be a robust and effective intervention across the elementary, middle school, and high school levels. Mooney and Laubach (2002) engaged middle school students in the Adventure Engineering (AE) program – a math and science adventure-driven and engineering-based curriculum utilizing multiple inquiry-based and open-ended activities that immerse students in engineering design processes. They found that students' engagement in hands-on engineering activities through the AE program improved students' attitudes towards math, science, and engineering. In a more recent study, Hammack et al. (2015) engaged 19 middle school students in a week-long engineering camp were students completed several engineering design activities. Findings showed that students' understanding of what technology is and what engineers do improved alongside their attitudes towards engineering and technology. Students' engagement in hands-on engineering design activities could have accounted for these improvements. In another study, Elam et al. (2012) engaged 62 middle and high school students in a two-week summer program aimed at increasing students' interest in learning STEM subjects. The program not only engaged students in an engineering design project but started with collaborative hands-on learning activities, industry tours, and interactions with career engineers. Results show that students developed positive attitudes towards engineering after engaging in the program (Elam et al., 2012).

It is worth noting that interventions by Elam et al. (2012) and Hammack et al. (2015) were implemented within a two-week time-frame but produced positive results, which could imply that engaging students in engineering design activities for as little as a week or two could positively impact their attitudes towards engineering. Studies by Mooney and Laubach (2002), Hammack et al. (2015), and Elam et al. (2012) are similar in that they all exposed middle school students to authentic engineering design activities and provide evidence that this intervention significantly improves students' attitudes towards engineering.

In this section, studies discussed so far merely engaged students in engineering design activities to improve their attitudes towards engineering. This paragraph shifts the focus by discussing studies that not only engaged students in engineering design activities but also tied such activities to students' local communities. In the study by Guzey et al. (2016), 275 middle school students participated in an engineering design-based science curriculum tied to students' local context. Based on the decline of the loon population in the state due to habitat loss, students designed loon nesting platforms and developed models of food webs to understand and provide solutions to the challenge. Brevik et al. (2014) also tied students' engineering-design activities to students' local context. Two eighty-five middle and high school students worked as members of a company for a full day to identify and create solutions to real-world problems through the engineering design process. Unlike Guzey et al. (2016) who only engaged students in engineering design activities, Brevik et al. (2014) also allowed students to communicate their findings to a boardroom consisting of the school board, community stakeholders, and industry representatives. While results from both studies showed that students' participation in authentic engineering design activities significantly improved students' attitudes towards engineering, Brevik et al. (2014) also found that students improved their attitudes towards engineering-related careers. Compared to students in Guzey et al. (2016), those in Brevik et al. (2014) showed improvements in their attitudes towards engineering and engineering-related careers. It is plausible that this difference could be accounted for by students' engagement in communicating their findings, consistent with what real-world engineers do. It is worth noting that although

Guzey et al. (2016) and Brevik et al. (2014) stress the influence of students' exposure to engineering design activities, their results could also be accounted for by connecting students' engineering design activities to students' local contexts. In the two studies, the grade-levels of the participants differed but the findings are similar, possibly suggesting that the intervention is effective at middle and high school levels.

The studies discussed in this section highlight the importance of engaging students in authentic hand-on engineering activities to bolster their attitudes towards engineering (Brevik et al., 2014; Cunningham & Lachapelle, 2010; Elam et al., 2012; Guzey et al., 2016; Hirsch et al., 2007; Mooney & Laubach, 2002). By engaging students in authentic hands-on engineering activities, students are exposed to and begin to understand what engineering is about and what engineers do, which could potentially dispel negative stereotypes students may hold against engineers and the engineering field. Brevik et al. (2014) add that increasing students' awareness of engineering-based careers and overcoming their stereotypes can change their attitudes towards these careers. Students' knowledge of a profession can significantly influence their career decisions (Hammack et al., 2015). Situating such interventions within students' local contexts is equally effective, as demonstrated by Guzey et al. (2016) and Brevik et al. (2014).

The Role of Place in Learning

Paul Theobald (2006) views place as a "lens through which to view the utility and practicality of traditional school subjects and as a catalyst for the development of deep understanding in traditional school subjects among the nation's youth" (p. 315). But contemporary school reforms often emphasize state-mandated standards and school accountability (Gruenewald, 2003), which can discourage schools from paying attention to place (Gruenewald, 2003), creating a disconnect between students' lived experiences and school learning (Smith, 2002). The disconnect between students' school learning and their lived experiences is problematic as it hinders meaningful learning and robs their communities of students' intellectual resources. One way to bridge the gap between students' school knowledge and their lived experiences is by using place-based learning or place-conscious learning (Buxton, 2010; Gruenewald, 2003; Johnson et al., 2009; Lee et al., 2012).

Place-Based Learning

Place-based learning is rooted in the progressive education movement championed by American pragmatists such as John Dewey and William James (Sobel, 2004). It uses students' local community and environment to teach concepts (Sobel, 2004) and connects learning to the local ecological, cultural, and historical settings in which education occurs (Elfer, 2011). It centers the educational process around particular situations, events, and experiences of the communities where schools are located (Elfer, 2011). Place-based learning emphasizes practical, real-world learning experiences (Sobel, 2005). Thus, it is experiential and involves hands-on activities (Orr, 1992; Woodhouse & Knapp, 2000).

For children, important information relates to their social environment and allows them to participate in activities appreciated by those they care about and respect (Smith, 2002). Place-based educators believe that focusing instruction on students' local context makes learning relevant to students (Brooke, 2003). Solving real-world problems affecting students' lives ignites their motivation for learning (Buxton, 2010; Duffin et al., 2009). When students are engaged in solving challenges affecting their communities, they develop stronger connections with their communities (Metzger, 2013; Smith, 2002). In addition, research has shown that place-based education effectively improves students' academic achievement and sense of stewardship in their environments (Chawla, 1998; Duffin et al., 2009; Smith, 2002; Sobel, 2004). Sobel (2005) adds that place-based learning boosts academic success, aids students in forging closer links with their communities, develops students' awareness of nature, and fosters a stronger desire to be active, contributing citizens (p. 7).

The National Science and Engineering Report indicates that one way to increase students' STEM interest is by "promoting personal relevance and situating the investigation in socially and culturally appropriate contexts" (National Academies of Sciences, 2019). Students experience increased levels of engagement when they learn content that is relevant to them and helps them recognize their competencies (Westbrook, 2021). This is especially true when such learning involves hands-on experiences (Lara-Prieto et al., 2019). Engagement refers to involving students in meaningful learning experiences (Delialioğlu, 2012) and is crucial because it impacts students' interest in learning (Lara-Prieto et al., 2019). Educators must leverage students' local knowledge and community experiences to increase students' engagement (Gruenewald & Smith, 2014).

Place-based learning allows educators to use students' questions as a basis for conducting classroom investigations, encouraging them to become knowledge creators rather than consumers (Smith, 2002). Investigating local phenomena can further serve as a basis for exploring abstract phenomena, which could increase students' sense of ownership of such investigations (Smith, 2002). Place-based learning also helps youths strengthen their sense of belonging in the natural world and human communities (Metzger, 2013). Hagerty et al. (1996)

add that sense of belonging is "the experience of personal involvement in a system or environment so that persons feel themselves to be an integral part of that system or environment" (p. 172). Metzger (2013) asserts that place-based education helps students develop an increased sense of belonging by deepening their relationships with their environments and communities.

Place-Conscious Learning

Some scholars have used place-based education interchangeably with terms such as place-consciousness, pedagogy of place, community-oriented schooling, and bioregional education (Elfer, 2011). Place-conscious learning is a phrase created by Theobald (1997) and expands the term place-based learning. While place-based learning and place-conscious learning have many similarities (Elfer, 2011), place-conscious learning goes further to apply critical humanism and social justice traditions within education settings, which is the only significant distinction between place-based learning and place-conscious learning (Schroder, 2006). "Place-conscious education aims to work against the isolation of schooling's discourses and practices from the living world outside the increasingly placeless institution of school" (Gruenewald, 2003, p. 620). Place-conscious pedagogy incorporates a place's multifaceted and multicultural impact into educational practices. It includes cultural connections, local geography, and how they relate to other sociological factors (Greenwood, 2013). Place-conscious learning allows students and teachers to investigate their surroundings and take action within their spaces while considering how these actions connect to the global community (Elfer, 2011; Gruenewald, 2003).

Educators who ground their curricula in place allow students to connect school knowledge to their lives and communities (Smith, 2002; Westbrook, 2021). Place-conscious curricula are essential because they allow for bridging local STEM issues and formal school STEM knowledge, promoting youth's interest in STEM (Avery, 2013; Buxton, 2010; Johnson et al., 2009; Lee et al., 2012). Students participating in place-conscious learning begin to see the world as interconnected (Brooke, 2003). Also, place-conscious curricula allow students to ask questions about their surroundings, participate in their environment, and think about how it relates to the larger global society (Westbrook, 2021).

Connecting learning to place allows students to engage in more authentic learning (Gruenewald, 2003). Place-conscious education introduces students to the skills they need to "regenerate and sustain [their] communities" (Gruenewald & Smith, 2014) and helps students develop an interest in their communities (Rotgans & Schmidt, 2018). It improves students' "dispositions, understandings, and skills required to restore and democratize humanity's adaptive capabilities" (Davies, 2008, p. xx). Place holds culture and identity (Gruenewald, 2003).

The literature above provides evidence that situating learning in place offers many benefits that impact students' learning. It is also essential to consider implementing such pedagogical approaches to students at an early age. Theobald (1997) stresses the importance of introducing students to the practice of researching about issues that vex their communities beginning in elementary school. This resonates with the present study, which engaged elementary students in multiple place-conscious engineering activities.

Theoretical Framework

This study used Social Cognitive Career Theory (SCCT) as a lens for studying students' engineering identities and attitudes towards engineering and technology. Albert Bandura's

(1986) general social cognitive theory influenced the development of SCCT. SCCT also draws from other cognitive-oriented career theories, such as Hackett and Betz (1981) Career Self-efficacy Theory (Barak, 1981; Schunk, 1989). SCCT was developed to assist in understanding the career progression of various individuals, encompassing a diverse range of students and workers. This includes individuals from different racial and ethnic backgrounds, cultures, genders, socio-economic statuses, ages, and disability statuses (Lent et al., 1994).

SCCT emphasizes the importance of cognitive factors and the interplay between self-referent and social processes to explain career behavior, choices, and growth (Lent et al., 1994). In the past few decades, researchers have increasingly focused on cognitive variables and processes in studying career development (Lent et al., 1994). This focus has helped researchers identify individuals' responsibility in shaping their career growth (Lent et al., 1994). SCCT has been significantly valuable and applicable in understanding several issues, including those related to academic achievement, organizational management, health choices, and emotional behavior. (Lent et al., 1994).

Major Components of Social Cognitive Career Theory

Building from Bandura (1986) general social cognitive theory, SCCT recognizes (1) self-efficacy, (2) outcome expectations, and (3) personal goals as the fundamental building blocks of individuals' career development. SCCT further explains the complex interplay between these three constructs (Brown, 2002). Of the three components, the self-efficacy piece has received the most attention in research on career development (Hackett & Lent, 1992; Lent & Hackett, 1994).

Self-Efficacy. Self-efficacy is an individual's judgment of their capability to successfully complete a particular task to produce specific results. There are four primary sources of self-efficacy: mastery experiences, vicarious experiences, verbal persuasion, and physical and psychological states (Bandura, 1977).

Mastery experiences consist of the past experiences individuals draw upon to assess their ability to successfully accomplish a particular task(Bandura, 1977). According to Bandura, students' past experiences can have lasting effects on their perceived self-efficacy (Usher & Pajares, 2008). Positive past experiences, such as successfully completing a task, support individuals' self-efficacy growth, while negative experiences, such as failure to complete a task, undermine their self-efficacy growth (Usher & Pajares, 2008). Success in overcoming challenging tasks has a more significant favorable influence on an individual's self-efficacy than success in overcoming less complex tasks (Bandura, 1977).

Vicarious experiences include an individual's observations of others completing certain actions, which serve to assess their capability to perform similar actions (Bandura, 1977). Individuals develop a sense of self-efficacy by observing their peers' performance on specific tasks and comparing it to theirs (Bandura, 1977). For example, when students observe their peers succeed in completing a challenge, their confidence to complete the same task can potentially increase (Usher & Pajares, 2008). Bandura (2003) notes that vicarious experiences are not only derived from close peers but also from individuals who are far away, such as those seen in the media. Individuals also seek vicarious experiences from individuals they perceive as well accomplished - whose accomplishments they admire and aspire to achieve. While most vicarious experiences involve individuals comparing themselves to others, they can also involve comparisons between individuals’ past and present achievements (Usher & Pajares, 2008).

Physiological and emotional states consist of an individual's physical and emotional well-being playing a vital role in shaping individuals' assessment of their abilities to accomplish tasks (Bandura, 1977). Students who experience anxiety in a particular class can interpret this emotional response as a sign that they lack the ability to complete that task (Usher & Pajares, 2008). Such emotional responses can determine students' chances of succeeding or failing, which can, in turn, influence their self-efficacy. While different levels of emotional states produce different perceptions of self-efficacy, Bandura (1997) asserts that individuals perform best when their emotional states are neither too low nor too high but relatively moderate.

Verbal persuasion is the process of influencing an individual's self-efficacy beliefs through the use of words communicated verbally or in writing (Bandura, 1977). Individuals develop perceptions of self-efficacy based on how others judge their abilities to complete specific tasks (Bandura, 1977; Bandura, 1997). For example, the feedback students receive from their peers and teachers can inform the development of their self-efficacy on a particular task. Praising and encouraging students for their performance can increase their self-efficacy, while the opposite can undermine it (Usher & Pajares, 2008).

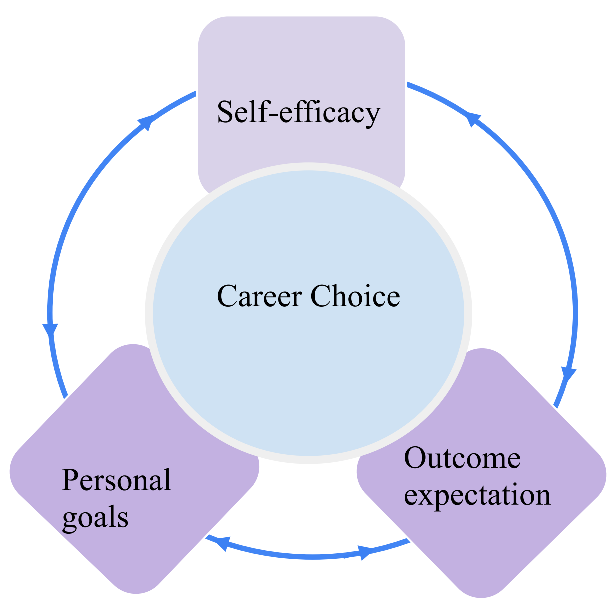
Outcome Expectations. Outcome expectations include individuals' beliefs about the results of engaging in a particular behavior (Lent et al., 1994). Research indicates that outcome expectations strongly predict individuals' intentions and behaviors (Flores et al., 2010; Yeagley et al., 2010; Zikic & Saks, 2009). Individuals can assess the result of specific behaviors based on their past personal experiences and the consequences of similar actions from others (Lent et al., 1994). According to SCCT, outcome expectations influence people's career interests, decisions, and behaviors (Ali et al., 2005; Gore Jr & Leuwerke, 2000; Wöhrmann et al., 2013). Individuals tend to choose career paths that are likely to produce positive results (Gore Jr & Leuwerke, 2000). They can also set goals solely based on the likelihood of achieving their desired outcomes (Gore Jr & Leuwerke, 2000; Lent et al., 1994).

Personal Goals. Personal goals are a fundamental aspect of all theories of career choice or decisions (Lent et al., 1994). Goals are an individual's resolve or intention to participate in a specific activity or achieve a desired result in the future (Bandura, 1986). Setting goals allows individuals to manage their behaviors (Lent et al., 1994) and exert personal agency to empower themselves (Brown, 2002). According to SCCT, individuals engage in activities that are consistent with their career goals (Lent et al., 1994).

The Interplay between Self-Efficacy, Outcome
Expectations, and Personal Goals

SCCT highlights relations between self-efficacy beliefs, personal goals, and outcome expectations (Gore Jr & Leuwerke, 2000). The relationship between these three components of SCCT and how they collectively influence career development is summarized in Figure 1.

Figure 1:Relationship between components of SCCT



Self-efficacy, outcome expectations, and personal goals are not isolated but interconnected (Lent et al., 1994). An individual's self-efficacy and outcome expectations can influence their goals and efforts to achieve them (Lent et al., 1994). Also, achieving one's goals can influence their self-efficacy and outcome expectations (Lent et al., 1994). An individual's self-efficacy can influence their outcome expectations, especially when the outcome of an action depends on an individual's capabilities to complete specific actions (Lent et al., 1994).

<u>Contextual Factors of Social Cognitive Career Theory</u>

The major factors (self-efficacy, outcome expectation, and personal goals) influencing individuals' career development do not act in a vacuum but with **c**ontextual factors. Contextual factors include individuals' culture, gender, genetic characteristics, socio-economic status, and state of health (Lent et al., 1994). While career development can depend on such factors beyond individuals' control, it is also largely influenced by their volition and cognitive characteristics, which can be flexible and thus susceptible to change (Lent et al., 1994). Contextual affordances such as exposure to role models, emotional support, and financial support can bolster or hinder individuals' career aspirations and development (Ali et al., 2005). Notably, such affordances impact individuals' learning, influencing their self-efficacy and, in turn, their outcome expectations (Ali et al., 2005). Research shows that students' level of support from their parents, peers, and teachers predicts their career aspirations, self-efficacy, intentions to persist in school, and outlook of opportunities from schooling (Ali et al., 2005).

Another factor influencing individuals' career development is their interaction with the environment. SCCT recognizes Bandura (1986) triadic-reciprocal model of causality, in which the relationship between behavior and person-environment is fully bi-directional, with behavior and person-environment equally influencing one another. In this system, individuals' behaviors shape the situations they find themselves in, impacting their thoughts, emotions, and subsequent behaviors (Bandura, 1982). The triadic system considers humans not only as producers but also as products of their environment (Wood & Bandura, 1989). By and large, SCCT posits that human behavior and person-environmental interactions equally impact each other and collectively impact career behavior, decisions, and development.

Chapter Summary

This chapter explored literature on engineering identity, the role of attitude in learning, the role of place in learning, and SCCT. The researcher discussed engineering identity as a relatively new and still underdeveloped research area, especially at the elementary school level. This section stressed the importance of students' engineering identity as an important factor influencing their engineering career choices, persistence in learning engineering, and retention in engineering programs. The discussion also highlights details of a framework asserting that performance/competence, recognition, and interest influence students' engineering identities. In the final piece of this section, the researcher reviewed how some prior studies used hands-on engineering activities to influence students' engineering identity development.

In the section focusing on the role of attitude in learning, the researcher discussed attitude as an essential factor influencing individuals' inclinations to engage in specific actions and behaviors. This discussion positioned students' attitudes towards engineering as a powerful construct impacting their persistence in learning engineering and their decisions to pursue engineering careers. Based on prior studies, the discussion also highlighted strong links between students’ engagement in authentic engineering activities and the development of positive engineering attitudes.

The section focusing on the role of place in learning discussed place-based and place-conscious learning as two interrelated constructs that help students establish links between school engineering curricula and local community engineering issues. This section stressed the importance of teachers situating their engineering lessons within students’ local contexts to enhance students’ classroom engagement and participation in addressing local community challenges.

The last section of this chapter discussed SCCT as the theoretical framework guiding this study. This section identified self-efficacy, outcome expectation, and personal goals as key SCCT components influencing individuals’ career development. It further explored how these interconnected components operate within individuals’ contexts (i.e., socio-economic status, gender, culture, etc.).

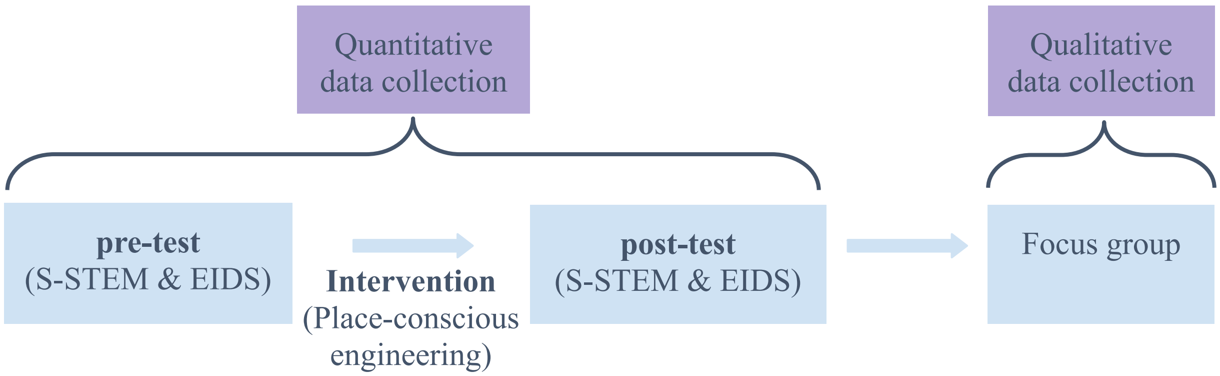
CHAPTER THREE

METHODOLOGY

Research Design

This study used an explanatory sequential mixed methods (quan → QUAL) research design (Mills & Gay, 2019). According to Mills and Gay (2019), an explanatory sequential mixed methods research design involves collecting and analyzing quantitative data before qualitative data and using qualitative data to support quantitative data. Mixed methods research designs allow researchers to leverage the complementary strength of quantitative and qualitative methods, offsetting the weaknesses of either method alone (Clark et al., 2008). Ultimately, mixed methods research designs can lead to a better understanding of a research problem (Taherdoost, 2022). In this study, quantitative data about students' engineering identities and attitudes towards engineering and technology is examined. Then, qualitative data is used to better understand participants' experiences with the engineering activities they completed in the past year. The researcher mixed together and interpreted findings from the two data types. This approach helps to explain trends observed in quantitative data and leads to a more comprehensive and nuanced understanding of the research problem.. Figure 2 shows a summary of this study's research design.

Figure 2: Summary of Research Design



Participants of this study included 20 fourth-grade students (n_{female} = 10, n_{male} =10) from a public elementary school in southwest Montana. The National Center for Educational Statistics (NCES) classifies the locality of the school as a rural territory, specifically designated as rural - fringe (41). This means that the school was located less than or equal to five miles from an urbanized area or less than or equal to 2.5 miles from an urban cluster (National Center for Educational Statistics, n.d.). At the time of the study, the school had approximately 434 pre-kindergarten to fourth-grade students, with 205 identifying as female and 229 as male. In terms of racial/ethnic background, 386 identified as White, 29 as Hispanic, and 19 as belonging to two or more racial/ethnic backgrounds.

The researcher purposefully chose these student participants because their teacher, Emma (pseudonym), was part of a larger National Science Foundation (NSF) project focused on improving rural and reservation students' interest in and awareness of engineering careers. The project engaged teachers from rural and reservation schools who collaboratively completed several professional development activities involving (1) brainstorming activities that would connect classroom engineering to students' local environment and (2) planning and developing year-long place-conscious engineering curricula for their students. Emma's participation in the project and experience in planning and implementing place-conscious engineering activities made her class a suitable sample for the present study. The researcher obtained informed consent from students' parents, and the study followed the protocol approved by the Montana State University Institutional Review Board (IRB).

Data Collection

Quantitative data were collected using the upper elementary (fourth-fifth grades) version of the Student Attitudes Toward STEM Survey (S-STEM) (Friday Institute for Educational Innovation, 2012) and Engineering Identity Development Scale (EIDS) (Capobianco et al., 2012) instruments. Qualitative data were collected through semi-structured focus group interviews.

The S-STEM is a validated instrument used to measure students' attitudes towards STEM fields (Unfried et al., 2015). Unfried et al. (2015) created the upper elementary version of the S-STEM by rewording items in the middle/high school version of the S-STEM in a way that made the language appropriate for fourth to fifth graders. Two subject matter experts reviewed the subscales of the upper elementary S-STEM to ensure the instruments satisfied conditions for content validity. After interviewing five fifth-grade students who provided feedback on the instrument, the authors revised the instrument to enhance its clarity. Authors assessed the suitability of the language used in the instrument by engaging 10 elementary school teachers to rate each item as "too easy," "just right," or "too hard" (Unfried et al., 2015, p. 625). Unfried et al. (2015) validated this instrument using data collected from 4181 fourth and fifth grade students (768 in the year 2011 and 3413 in the year 2012) participating in STEM education programs in rural public schools across a Southeastern state. This sample's gender distribution was approximately equal between male and female groups (50.7% male and 49.3% female). In terms of race/ethnicity, 59.7% self-identified as White/Caucasian, 14.8% as Black/African American, 9.8% as Hispanic/Latino, 4.5% as multiracial, 5.1% as American Indian, 0.5% as Asian, 0.6% as Pacific Islander, and 5.1% as Other. Unfried et al. (2015) performed an exploratory factor analysis, which suggested a four-factor model (i.e., science, technology and engineering, mathematics, and 21st-century skills) for the upper elementary S-STEM. Then, they confirmed this factor model using confirmatory factor analysis.

The S-STEM contains 5-point Likert scale items spread across four factors: science (9 items with $\alpha = 0.83$), engineering and technology (9 items with $\alpha = 0.84$), mathematics (8 items with $\alpha = 0.85$), and 21st-century learning (11 items with $\alpha = .87$). Additionally, it contains a factor, your future, with 12 4-point Likert scale items, and a factor, about yourself, which contains 10 3-point Likert scale items. However, this study only used the nine items under the factor, engineering and technology. This is because they align with one of the primary foci of this study, which is to measure students' attitudes towards engineering and technology.

The EIDS is a 16-item validated instrument consisting of 3-point Likert scale items used to measure elementary (grades 1-5) students' engineering identities (Capobianco et al., 2012). The EIDS was developed using a three-phase process, including (1) the construction of the EIDS, (2) administering the EIDS to the first sample, and (3) administering the EIDS to the second sample. In phase one, the authors administered the first draft of the instrument to (1) elementary, undergraduate, and graduate students in STEM education, (2) elementary and STEM university educators, and (3) university professors working on the project. The authors used feedback from these groups to revise four drafts of the EIDS and produced the 20-item EIDS spread across four factors: (1) academic identity, (2) school identity, (3) occupational identity, and (4) engineering aspirations. In phase two, teachers completed a professional development workshop introducing them to developing and implementing engineering curricula incorporating hands-on engineering activities. The teachers completed a six-week engineering unit with 184 students who had no prior engineering knowledge. The authors administered the pre- and post-surveys of the EIDS. Participants' racial distribution included 72% White, non-Hispanic; 21% Black, non-Hispanic; 3% Hispanic; 3% Asian; and less than 1% American Indian. Forty-six percent of students were eligible for reduced free lunch. In phase three, the authors reviewed the findings of the pilot study in consultation with the students' teachers, allowing them to make appropriate changes to the instruments, such as increasing the font size, limiting the number of items displayed per page, printing the instrument on a bright paper, and replacing the names of the 3 points (i.e., no, not sure, and yes) of the Likert scale to smiley faces. Then, the authors administered pre and post surveys of the new version of the EIDS to 213 students, including the initial 184 students who participated in the prior pilot study (Capobianco et al., 2009). Exploratory and confirmatory factor analyses resulted in 16 items distributed across two factors: academic identity (6 items with $\alpha = 0.58$) and engineering career identity (10 items with $\alpha = 0.70$) (Capobianco et al., 2012). The present study used all the items of the EIDS.

Students completed the S-STEM and EIDS instruments before and after the intervention. The S-STEM and EIDS surveys provided quantitative data that was then used to assess the impact of students' participation in place-conscious engineering activities on their engineering identities and attitudes towards engineering and technology. The researcher used focus group interviews to collect qualitative data to explain how the students described their engagement with engineering activities in relation to their engineering identities and attitudes towards engineering and technology. Compared to in-depth interviews, focus group interviews allow participants to interact and collaboratively expand contributions to the discussion using the points raised by other participants (Powell & Single, 1996). Focus group interviews also enable researchers to effectively identify the complete range of participants' opinions, beliefs, experiences, and perspectives (Powell & Single, 1996). They are comparatively more time-effective (Kelly, 2003) and cost-effective than in-depth interviews (Escalada & Heong, 2014).

At the end of the school year, focus group interviews were conducted by an NSF project team member who had been visiting the students' science classes an average of 2-3 times per month during the school year. Prior interaction with the project member allowed students to participate freely in the interview sessions because they had developed a rapport and became comfortable with the individual. McGrath et al. (2019) stress the importance of researchers building rapport and comfortable interactions with their participants long before conducting interviews. Familiarity with participants makes it easy for researchers to connect with participants during the interview, allowing participants to provide rich and detailed accounts of their experiences (McGrath et al., 2019).

Emma purposely divided the students into six groups of three to four students per group based on students' personalities and interpersonal skills. Each group of students participated in a semi-structured focus group interview lasting between eight and nineteen minutes. The professor conducted these interviews in a flexible learning space outside the participants' classroom within the school – a place participants were already familiar with. Conducting interviews in a familiar and comfortable place for participants is necessary for effective data collection (McGrath et al., 2019). During the interview, participants answered several questions about their engagement with engineering activities in the past year. The semi-structured interview protocol consisted of three questions: (1) Tell me about the engineering activities you did in class this year. (2) What do you think engineers do for their jobs? (3) Would you want to be an engineer when you grow up? Why or why not? The interviewer asked follow-up questions based on the participant's responses to these questions.

Intervention

Students participated in a year-long science curriculum that incorporated two place-conscious engineering activities: (1) designing and developing air filters for wildfire survivors whose residences were polluted with smoke that was unhealthy for breathing and (2) designing flood prevention strategies for addressing floods that often occur on a local river in winters due to ice-jams.

Designing and Building Air Filters

The description of this intervention is solely based on Rapstad et al. (2023). Specifically, the section where the authors describe how they engaged elementary students in designing and building box fan air filters for wildfire survivors. Readers who wish to read the original content can access it from Rapstad et al. (2023).

This study was conducted in a state where wildfires are a major issue. The problem became more pressing in the Fall of 2021, when a wildfire ravaged a small, nearby community where Emma's brother lived. This made breathing unhealthy as the air quality index approached dangerous levels. Given the students' experiences with local wildfires in the previous years, they understood the negative impacts of wildfire smoke, and wanted to help Emma's brother and other affected families. Emma designed and implemented a place-conscious engineering activity that could mitigate the problem. Through three lessons, Emma guided her students to design and build box fan air filters for affected wildfire survivors. The following three paragraphs provide details about these lessons.

First lesson. The first lesson focused on studying the problem to understand it better and identifying potential remediating strategies. During the first lesson, Emma engaged her students in a discussion highlighting the wildfire smoke problem that affected a nearby community where Emma's brother lived. Emma stressed the dangers of wildfire smoke and allowed her students to read news stories about the wildfire. Then, the class discussed possible causes of the wildfire, including major droughts, the lack of snow, and a heavy presence of kochia. Through readings, students learned that wildfire smoke contains fine particles, which if inhaled, can enter the bloodstream and cause significant health problems.

Emma put students in groups of four, selecting each group member based on their abilities. In these groups, students discussed possible ways of designing and building a product that takes away and prevents smoke from entering the affected families' homes. When they finished their group discussions, they discussed the same topic as a class. Students considered designing and building a device that would use negative pressure to remove smoke from the affected homes, but realized it would be a complex task. So, they continued thinking and discussing alternative remediation strategies. After much debate, the class resolved to build box fan air filters to mitigate the effects of the wildfire smoke for the affected community. This product would be made of air filters and cardboard with a box fan mounted on one side.

Second lesson. The second lesson focused on planning and testing the box fan air filters. Emma started the second lesson by reviewing information learned and discussed during the previous lesson. Then Emma provided students with all the materials they needed to build their box fan air filters. She put them into six groups of four students each to plan how they would build the air filters. To help students navigate the engineering design process, Emma provided the students with an engineering design notebook, which students used throughout the lesson. The six groups of students collaboratively planned and designed box fan air filters. Then, they built and tested their performance against set criteria and constraints. Testing revealed that some designs worked well, while others failed. So, Emma wrapped up the lesson by discussing what made some designs work, and others fail. This allowed her to assess students' attitudes towards the engineering design process and emphasize that failure in engineering is typical and part of the engineering design process. This discussion reinforced Emma's prior lessons about managing emotions due to the failure of engineering designs.

Third lesson. The third lesson focused on redesigning the box fan air filters to ensure they met set criteria. Emma provided student groups with instructions for creating a Corsi–Rosenthal box, allowing them to modify and improve the functionality of their product. For some groups, this involved adding more tape to strengthen and better seal the joins. For others, it involved dismantling their products and building improved versions. Eventually, all the groups completed building the air filters to the expected standards. Two volunteers transported the box fan air filters to a central place within the affected community. Then the affected families collected them.

Flood Prevention Plans

Ice jams are common along the state's rivers, especially between January and March. After the state issued ice jam warnings a few weeks apart, Emma used this to connect classroom engineering to students' local community issues. She engaged her students in five days of instructional lessons. Specific details of the lessons are discussed in the following paragraphs.

First lesson. This lesson focused on learning about floods through watching videos and reading. First, students watched a video showing how ice jams caused floods on a local river and discussed what they observed in groups and then as a class. To assess their prior knowledge about floods, students individually completed a survey with a single multiple-choice question that their teacher had created. Then, they used their notebooks to answer a question about how engineers and other people limit the effects of flooding. During this process, Emma walked around the class to observe students and provide guidance when necessary.

Emma and her students read a textbook section highlighting the floods that damaged expensive property (i.e., homes, cars, land, and animals) in New Orleans, Louisiana in 2005. The text also discussed how floods could help replenish soil nutrients and moisture to support plant growth when they flow on infertile and dry lands. Before reading the text, Emma had given each student a cause-and-effect chart. Students used the cause-and-effect chat to write down any causes (i.e., why floods happen) and effects (i.e., what happens after a flood) they observed from the text. Emma advised the students to jot down essential keywords and notes from the text they believed they would need to remember. Using the glossary, students looked up meanings of keywords to help them better understand the text they read. Some of the keywords students captured included levee and floodplain.

Then, students discussed the causes of overbank flooding, noting factors such as heavy rains, ice jams, and snow melt. During this lesson, Emma constantly walked around the classroom. She asked students probing questions to scaffold their thinking, help them understand how floods happen, and provide insights into flood prevention measures. Emma assured students they would interact with a local floodplain engineer and discuss how the engineers prevent floods or mitigate their effects to help people.

<u>Second lesson.</u> Emma invited a local floodplain engineer to share his experiences working with flood prevention in the state. The engineer used modeling software to show students a two-dimensional model depicting a possible flood in a nearby town. While studying the flood, the engineer drew the students' attention to popular landmarks in the model to enhance their sense of place. The modeling software used arrows to show the direction of waterflow. This allowed the students to observe how the water would flow and see the areas that would be affected if a flood occurred. Then, students could imagine potential flood challenges and ponder potential solutions.

Next, the engineer engaged students in a simulation activity using a physical floodplain simulator. He asked students to build model houses that were later placed in different locations around the river. In completing the simulation activity, the engineer assigned students to play different roles such as rainmaker, hydrologist, and scientist. Students who took the role of rainmakers dumped water into the natural headwaters, which flowed into a river on the simulator. Those who participated as hydrologists measured water elevation readings from the staff gage. Finally, those who worked as scientists recorded data measured by hydrologists. Students observed and studied how floods happen and noted how the floods impacted the area around the river. Students repeated this activity by replacing the natural headwaters with a parking lot. Compared to the natural headwaters, the parking lot was impermeable, allowing the flood water to rise to higher levels and cause more significant damage.

Then, the engineer used the flood simulator to demonstrate possible engineering solutions to address flooding. He discussed with the students the ways in which humans adapt to flooding. These included (1) building large protective structures such as dams and levees, (2) identifying or mapping floodplains, (3) building in strategic places (i.e., areas less affected by floods), and (4) building on elevated structures such as stilts or mounded soil to prevent floods from reaching and damaging houses. Throughout the lesson, the engineer emphasized the need to be persistent and resilient in designing and implementing solutions to address floods. He also stressed that engineering solutions should be carefully considered to prevent causing harm to the natural environment.

<u>Third lesson.</u> The third lesson focused on learning how engineers mitigate the effects of natural disasters such as floods. Emma started the second lesson by reviewing the information students had learned during the previous lessons. Students worked in groups of about four, discussing the meaning of the terms they recorded from the previous lesson (i.e., levee, flood plain). They discussed why some people built houses or lived in floodplains despite flood risks. Emma gave each group of students the floodplain models they built earlier. Using the flood plain

models, students worked in groups to decide and mark the best positions to place three different model houses to minimize the damage these model houses would sustain if a flood occurred.

While this happened, Emma engaged students in conversations that elicited their thinking, allowing her to assess and support them. Students studied flooding using three trials while working in groups. In the first trial, some students poured water in the floodplain models to simulate rain on a river, while other students used data sheets to record observations of where the water overflowed, and which houses would be damaged if they were there in the marked positions. The second trial involved increasing the amount of water poured on the model floodplain, and all the floodplain models overflowed. Finally, the third trial involved placing levees at different positions to prevent the floods from affecting the model houses.

Fourth lesson. Emma gave each group of students a chart paper with a drawing of the model of a floodplain. Each group compared the river on the model to the drawing on the chart paper. They used the chart paper to mark the approximate positions where they placed their model houses and drew arrows showing the direction in which the water overflowed during the second trial. Then, students used the chart papers to design solutions to prevent the model houses from flooding. They drew and labeled modifications they would perform (i.e., placing a levee, modifying the house's structure, or changing the position of the house) to solve the problem. Emma asked students not to modify the river because, in the real world, it can negatively impact aquatic life and other living organisms that depend on the rivers. She also stressed the need to minimize changes to those with the most impact, as real-world engineering involves using cost-effective designs.

Fifth lesson. During the final lesson, students continued designing flood prevention strategies. This time, they completed this task in groups and explained how their plans would protect the model houses from floods. Then, groups exchanged chart papers containing flood prevention strategies, examined their peers' strategies, and provided written feedback on sticky notes. Again, students exchanged their flood prevention strategies and provided peer feedback, focusing on feedback not captured by the previous group. Emma explained that real-world engineers seek peer feedback to improve their designs. Finally, all the groups received their strategies with peer feedback, which they used to examine, modify, and improve their flood prevention strategies.

Data Analysis

Quantitative Data Analysis

The researcher analyzed quantitative data from the S-STEM and EIDS using STATA version 18. Using listwise deletion, the researcher removed incomplete observations from the S-STEM and EIDS, reducing the number of participants from 23 to 20. Then, the researcher checked if the data from the S-STEM and EIDS met the assumption of a paired samples t-test. A paired samples t-test assumes that differences between paired observations (i.e., post – pre) are normally distributed (McDonald, 2014; Pandis, 2015). Using data from the S-STEM and the two factors of the EIDS (academic identity and engineering career identity), the researcher performed Shapiro-Wilk tests to check if the differences between paired observations were normally distributed. Results indicated that data from the S-STEM were normally distributed, allowing the researcher to use paired samples t-tests to compare students' pre and post mean scores. Additionally, while data from the engineering career factor of the EIDS were normally distributed, data from the academic factor of the same instrument were not. So, the researcher used a Wilcoxon signed-rank test to compare students' pre and post median scores of the two factors of the EIDS. Wilcoxon Signed-Rank test is the non-parametric alternative of the parametric paired samples t-test (Durango & Refugio, 2018; Field, 2013; Rosner et al., 2006). By examining each EIDS factor individually, the researcher gained a more nuanced and comprehensive understanding of students' engineering identities across the instrument's two factors. The researcher performed the paired samples t-test and Wilcoxon signed rank tests as one-tailed tests at a significance level of 0.05. For a fixed significance level, a one-tailed test has better statistical power than a two-tailed test for identifying differences in a specific direction (Lombardi & Hurlbert, 2009). The last piece of quantitative data analysis involved computing Cohen's *d* values to determine the intervention's effect size on the dependent variables and Cronbach's alpha values to determine the reliability of the S-STEM and EIDS. Effect sizes indicate the practical significance of research findings from studies focused on cause-effect relationships between variables (Bhandari, 2020; Field, 2013; Sullivan & Feinn, 2012), while Cronbach's reliability scores ensure that collected data are consistent (Riege, 2003).

Qualitative Data Analysis

The researcher analyzed qualitative focus group interview data using thematic analysis. Thematic analysis is a technique used to recognize, examine, and present recurring patterns or themes from qualitative data (Braun & Clarke, 2006). It often extends beyond this by interpreting different facets of the research topic (Boyatzis, 1998). Thematic analysis is a powerful method for understanding experiences, thoughts, or behaviors from qualitative data sets (Kiger & Varpio,

2020) such as focus group interviews, field notes, recorded observations, and journal entries (Kiger & Varpio, 2020; Nowell et al., 2017).

There are many ways of approaching thematic analysis (Alhojailan, 2012; Javadi & Zarea, 2016). Braun and Clarke's (2006) approach offers a clear, easy-to-use framework for completing thematic analysis, making this approach one of the most influential in social science research (Maguire & Delahunt, 2017). This study used Braun and Clarke's (2006) approach to conducting thematic analysis. The approach includes six steps: (1) familiarizing yourself with your data, (2) generating initial codes, (3) searching for themes, (4) reviewing themes, (5) defining and naming themes, and (6) producing the report. The following six paragraphs provide an overview of how the researcher used Braun and Clarke's (2006) approach to complete the thematic analysis.

<u>Step 1 (Familiarization with Data).</u> The researcher listened to the recordings of the semi-structured focus group interviews and transcribed them in a Word document. According to Wellard and McKenna (2001), transcription is a part of qualitative data analysis and should be explicitly explained in study methodologies. The transcription process involved listening to six interview recordings to gain familiarity with their content. The researcher used a verbatim transcription method involving word-for-word reproduction of verbal data (Bucholtz, 2000; Greenwood et al., 2017; Poland, 1995). Specifically, this involved writing every word the interviewers uttered, including false starts, self-correction, grammatical errors, and filler words. The researcher omitted recording pauses and non-verbal sounds such as laughter and sighs to expedite the transcription process while ensuring clarity and readability of the transcript. Verbatim transcription provides researchers with rich information, potentially promoting

accurate and rigorous qualitative data analysis (Halcomb & Davidson, 2006; MacLean et al., 2004). This is opposed to other transcription methods such as intelligent verbatim transcription. Intelligent verbatim transcription involves retaining the meaning of audio recordings but omitting stammers, false starts, repeated phrases, self-corrections, and filler words (Bucholtz, 2000; McMullin, 2023). It aims to preserve the meaning and context while minimizing linguistic clutter, which could lead to a reduction in accuracy (Bucholtz, 2000; McMullin, 2023). During the transcription process, the researcher listened to the interview recordings multiple times to capture all the words the interviewees uttered and wrote rough notes summarizing important initial observations and ideas from the interviews. The researcher used memo writing, close reading, and re-reading throughout the data analysis process (steps 1-6) to aid qualitative data analysis (Boeije, 2002).

Step 2 (Initial Coding). The researcher used the hybrid coding technique. Hybrid coding involves generating both theory-driven codes and data-driven codes, potentially leading to a more comprehensive identification of codes (Xu & Zammit, 2020). The researcher closely read the transcripts and listened to the interviews multiple times to generate open codes. According to Glaser (2016), open coding involves coding all the data in all possible ways. First, the researcher read the entire transcript and generated inductive (data-driven) codes from interesting pieces of text, a process that heavily relied on inductive thinking (Chandra & Shang, 2019). Inductive coding involves deriving codes from data to identify codes without having predetermined codes in mind (Chandra & Shang, 2019).

Secondly, the researcher generated deductive (theory-driven) codes that aligned with the study's literature, especially identity and SCCT theories. Deductive coding involves predefining codes, then assigning them to the data they match (Chandra & Shang, 2019). The researcher read the literature and noted concepts and ideas he believed would provide insights into answering the qualitative research question. These included concepts such as hands-on, place, societal utility, engineering identity, attitude, interest, engineering career interest, collaboration, etc. To illustrate this process, consider this example. Literature suggested that hands-on engineering activities impact students' engineering identities; to represent hands-on engineering, the researcher recorded the code "hands-on," looked for evidence of its presence in the transcript and assigned it to data it matched with. This is because, ultimately, the researcher hoped to understand what the interviews revealed about students' engineering identities.

This stage also involved developing a codebook containing a list of codes, their definitions, and examples of data fitting each code. The codebook helped the researcher code and analyze the data more consistently (Milford et al., 2017; Oliveira, 2023; Rogers, 2018), and facilitated data exploration and identification of themes (Miles et al., 2014). When selecting codes to include in the codebook, the researcher considered (1) relevance – codes related to the research question and (2) frequency – codes that appeared several times in the data, suggesting the presence of essential themes. The researcher defined these codes based on literature and the meanings of the data they represented. The researcher added new codes to the codebook and refined them as new concepts, ideas, and patterns emerged from the interview transcript (Reyes et al., 2021). Table 1 shows an excerpt of the codebook used in this study. It only contains three codes for illustration purposes, but the full codebook can be accessed from Appendix A of this thesis.

Table 1. Excerpt of the codebook used in this study

Codes	Definition	Examples of Data Fitting Code
Hands-on	Experiences requiring students' active participation by touching, manipulating, and exploring physical objects as part of completing engineering tasks.	"I really like how [Emma] does a lot of hands-on activities." "I like building air filters."
Societal Utility	Innovations that provide solutions to societies' challenges and improve the peoples' qualities of life.	"There was a big fire and there was a bunch of smoke in the air. It made it hard to breath for people. So, we made air filters for the Denton (name of town) people."
Collaboration	Students working together or completing a shared task to achieve a common engineering goal, leveraging their diverse perspectives, knowledge, and skill.	"Me and BX13 (pseudonym) were a team and like, we had many ideas, but we've tried them, and they didn't work. So, then we had ah, to think of another idea…"

Step 3 (Searching for Themes). Miles et al. (2014) stress that researchers can select meaningful codes by referring to applicable conceptual frameworks or research questions. The researcher closely examined all the codes and selected those that provided meaningful insights into answering the qualitative research questions. Then, the researcher grouped similar codes into potential theme and sub-theme categories, and labelled them with tentative names and definitions (Braun & Clarke, 2006).

Step 4 (Reviewing Themes). This analysis stage can involve creating, adding, or discarding themes (Kiger & Varpio, 2020). It can also involve creating miscellaneous themes containing "orphan codes" that do not fit well within existing themes (Braun & Clarke, 2006). The researcher re-examined the codes to ensure they were in the correct themes and sub-themes (Braun & Clarke, 2006). Then, the researcher (1) moved some codes from less compatible themes and sub-themes to more compatible ones, (2) created new themes and sub-themes to accommodate codes lacking adequate compatibility with existing themes and sub-themes, and

(3) removed codes that did not contribute valuable insights into addressing the research questions from the overall analysis.

Step 5 (Defining and Naming Themes). With the view of refining themes and sub-themes, the researcher continued to examine the relationship between codes and their respective themes and sub-themes (Braun & Clarke, 2006). Following changes made to themes and sub-themes in step 4, the researcher refined themes and sub-themes names and their respective definitions. This allowed the researcher to move to the next step without making changes to the analysis. At this point, the researcher had all the data to compile the results and directly address the study's qualitative research question.

Step 6 (Producing the Report). The final step involved compiling the thematic analysis results in Chapter 4 of this thesis. The researcher presented the results in narrative form and summarized emerging themes and sub-themes in a table. This section also included the researcher's interpretation of the data and why the selected themes and their interpretations were accurate and meaningful (Braun & Clarke, 2006; Braun et al., 2012).

Mixing of Quantitative and Qualitative Data

The final part of the data analysis was twofold: (1) checking if qualitative results supported quantitative results and (2) examining nuanced qualitative results that explained the quantitative results. Creswell (2014) explains that researchers can merge qualitative and quantitative data using a side-by-side comparison. This method involves presenting quantitative results and then discussing the qualitative results (i.e., themes from interviews) that support or do not support the quantitative results (Creswell, 2014). The researcher checked if qualitative data findings provided evidence supporting quantitative data findings. Then, the researcher discussed themes from qualitative results that could explain trends observed in the quantitative data. The researcher finally utilized the literature reviewed in this study to investigate potential underlying reasons for the observed level of agreement between the two data types and subsequently interpreted the findings collectively.

To further illustrate this process, consider this example. Quantitative results showed that students' participation in place-conscious engineering activities improved their attitudes towards engineering and technology. The researcher explained this quantitative outcome with the corresponding test statistic, degrees of freedom and p-value. Then, the researcher examined all the themes and found that "hands-on engineering activities" provided insights to better understand the quantitative results. The researcher developed one overarching explanation based on both quantitative and qualitative results. This was achieved by stating, "students' participation in place-conscious engineering activities improved their attitudes towards engineering and technology because they enjoyed participating in hands-on engineering activities and were actively involved in the learning process." The researcher backed up this explanation using relevant literature from chapter two of this thesis. While this example focused on one theme, this study considered all themes that either agreed or disagreed with the quantitative results.

Trustworthiness

The trustworthiness or rigor of a study pertains to the degree of confidence in the data, analysis, and techniques employed to uphold the study's quality (Polit & Beck, 2014). Researchers should provide clear descriptions of how they address trustworthiness because it determines the readers' confidence in research findings (Amankwaa, 2016). This section discusses several ways the researcher enhanced the trustworthiness of this study. The discussion focuses on three main areas: research design, Four-Dimension Criteria, and reflexivity.

Research Design

This study used a mixed methods research design, which enabled the researcher to leverage the synergetic strengths of quantitative and qualitative methods. Mixed methods research designs lead to a deeper understanding of research problems (Hurmerinta-Peltomäki & Nummela, 2006; Taherdoost, 2022) while minimizing the weaknesses inherent in either quantitative or qualitative methodologies alone (Clark et al., 2008). Some scholars contend that compared to studies that solely use quantitative or qualitative approaches, those using mixed methods research designs tend to have enhanced research validity (Hurmerinta-Peltomäki & Nummela, 2006; Molina-Azorín, 2010). In the present study, quantitative data allowed the researcher to determine the impact of the intervention on the dependent variables. Then, qualitative data complemented these findings by providing explanations for the trends observed from quantitative data. Therefore, the synergistic use of quantitative and qualitative approaches provided a comprehensive understanding of the research problem and enhanced the trustworthiness of the study.

Four-Dimensions Criteria

While quantitative researchers use internal validity, reliability, objectivity, and external validity to measure the rigor of their studies (Cook et al., 2002), qualitative researchers use credibility, dependability, confirmability, and transferability (Chowdhury, 2015; Guba & Lincoln, 1989). Lincoln and Guba developed these four measures of trustworthiness and called them the Four-Dimensions Criteria (FDC) (Forero et al., 2018). Credibility and confirmability are primary criteria while transferability and dependability are secondary (Megheirkouni & Moir, 2023). Qualitative studies that do not use any of the latter two criteria, do not necessarily fail to meet quality criteria (Megheirkouni & Moir, 2023). This section discusses how the researcher addressed credibility, confirmability, transferability, and dependability to enhance the trustworthiness of the present study.

Credibility. Credibility, in qualitative research is equivalent to internal validity in quantitative research (Chowdhury, 2015; Lincoln, 1995; Tobin & Begley, 2004). Megheirkouni and Moir (2023) define credibility as confidence in research findings, stressing that credibility checks if research findings emerge from data and represent the original meaning of data (Megheirkouni & Moir, 2023). To ensure this study was credible, the researcher: (1) engaged with the qualitative data (i.e., listening to the interviews and reading the transcripts) multiple times over several weeks to develop a comprehensive understanding of the data; (2) chose an appropriate data analysis method (in this case, thematic analysis) for answering the qualitative research question – a method that has a proven track record of producing reliable results; and (3) recorded the data analysis process which was constantly reviewed to search for and address potential biases (Megheirkouni & Moir, 2023). Additionally, to ensure that interviewees provided quality and authentic data, the interviewer (1) interacted with interviewees multiple times before the interview day to develop a comfortable rapport with the interviewees and (2) conducted the interviews in a familiar and comfortable place within the school grounds (McGrath et al., 2019).

Confirmability. Confirmability in qualitative research is synonymous to objectivity or neutrality in quantitative research (Tobin & Begley, 2004). It checks if research findings and interpretations emerge from data or if they emerge from the researcher's imaginations (Chowdhury, 2015; Tobin & Begley, 2004). The use of audit-trails is one of the acceptable strategies for addressing confirmability in qualitative research (Nowell et al., 2017). To ensure confirmability, the researcher developed an audit trail – a written account of how the data was analyzed and interpreted. This allowed the researcher to examine the audit-trail, and question and address approaches used to analyze and interpret data. Additionally, Koch (1994) stresses the need for qualitative researchers to clearly document reasons for using specific research methods and analytical approaches. Therefore, the researcher justified the selection and use of specific qualitative methods and approaches in the present study.

Transferability. Transferability in qualitative research is equivalent to external validity in quantitative research (Chowdhury, 2015; Tobin & Begley, 2004). It refers to the extent to which qualitative inquiry findings can be generalized and applied beyond the bounds of a study (Tobin & Begley, 2004). Lincoln et al. (1985) stresses the need for researchers to develop detailed descriptions of their qualitative studies to allow readers to decide the extent to which findings apply to their contexts. Therefore, the researcher described the study sample, intervention, qualitative data collection and analysis process in detail. This enhances transferability by providing readers with sufficient information to judge the applicability of the present study's findings to their contexts (Chowdhury, 2015).

Dependability. Dependability in qualitative research is comparable to reliability in quantitative research (Chowdhury, 2015; Tobin & Begley, 2004). It is a measure of how qualitative research finding are stable over time (Forero et al., 2018; Megheirkouni & Moir, 2023). Like transferability, dependability can be addressed using audit-trails, which allow for the re-examination of qualitative inquiry processes and findings (Forero et al., 2018; Tobin & Begley, 2004). Dependability is also addressed by writing descriptions of qualitative inquiry processes to allow for possible repetition of such inquiry in the future (Chowdhury, 2015). Therefore, the researcher developed an audit-trail and described the inquiry process in detail.

Reflexivity.

This section discusses the researchers' engagement with reflexivity to identify and address biases from the researcher's positionality. Reflexivity ensures that qualitative inquiry is trustworthy (Lambert et al., 2010). It permeates qualitative research in its entirety (Dodgson, 2019) and involves researchers purposively identifying, examining, and addressing their subjective points of views that could potentially influence research findings (Jamieson et al., 2023; Olmos-Vega et al., 2023). Researchers must understand how their identities (i.e., age, class, culture, education, ethnicity, gender identity, gender presentation, language, race, sexual orientation) and contextual factors (i.e., professional background, familial roles, historical influences) influence their research processes and results (Alvarez-Hernandez, 2021; Rogers, 2018). In the present study, the researcher engaged in reflexivity to enhance the trustworthiness of the study. A large part of this process involved writing and continuously editing his positionality statement to increase his awareness of potential biases (Alvarez-Hernandez, 2021).

The researcher realized that his status as a non-native English speaker with limited experience living in America could impact his understanding and interpretation of qualitative concepts (interviews) whose meanings are rooted in the American cultural context. Prolonged engagement with qualitative data is an essential part of achieving trustworthiness of qualitative research findings (Lincoln et al., 1985; Megheirkouni & Moir, 2023). Therefore, the researcher read and listened to the transcripts multiple times over several days and weeks to ensure they accurately captured the messages conveyed by interviewees, allowing for accurate interpretations and enhancement of the study's trustworthiness (MacLean et al., 2004).

Regarding educational background, the researcher knows that his physics background inclines him toward a positivist research paradigm, potentially causing confirmation bias where the researcher seeks data confirming existing theories or hypotheses. The researcher may also inadvertently ignore essential contexts that allow him to analyze and interpret interview data more fully and accurately due to his inclination to understand the world more objectively than subjectively. Researchers can improve their critical thinking and overcome biases by reflecting and writing about the data analysis process (Rogers, 2018). Therefore, the researcher wrote notes about the inquiry process in an audit-trail and recorded his thoughts and emotions while working with interview data. This allowed the researcher to re-examine the data with a focus on identifying and addressing potential biases.

Chapter Summary

This chapter discussed the research methods used to complete this study. Specifically, the chapter addressed the (1) research design (explanatory sequential mixed methods research design), (2) demographic information of study participants (fourth-grade students enrolled in an elementary school in Montana), (3) data collection methods (administration of EIDS and S-

STEM respectively; and focus group interviews), (4) data analysis methods (a t-test and Wilcoxon signed-rank tests to compare students' pre and post scores from the S-STEM and EIDS; thematic analysis to identify important themes; and using qualitative data to explain trends observed in quantitative data), and (5) trustworthiness of the study. The next chapter presents the findings of this study.

CHAPTER FOUR

RESULTS

Introduction

This explanatory sequential mixed methods study examined elementary students' engineering identities and attitudes towards engineering and technology when exposed to place-conscious engineering activities. Participants of this study were 20 fourth-grade students enrolled in an elementary school in southwestern Montana. In this chapter, the researcher systematically presents the results of this study according to the research questions. The researcher presents the results of the first two research questions as tables with descriptive and inferential statistics, accompanied by narratives. The results of the third research question are presented as a table showing themes and their respective codes and corresponding descriptions. Lastly, results from the fourth research question are given as narratives.

Quantitative Results

This section presents results from the quantitative piece of this study. The results are based on the pre and post data collected from two Likert scale instruments: (1) Student Attitudes toward STEM (S-STEM) and (2) Engineering Identity Development Scale (EIDS). The S-STEM has six subscales (i.e., science, technology and engineering, mathematics, 21st-century skills, your future, and about yourself) but the researcher only used the engineering and technology subscale (9 items). The EIDS contains two subscales: academic identity (6 items) and engineering career identity (10 items), and the researcher used both subscales. The S-STEM measured participants' attitudes towards engineering and technology while the EIDS measured their engineering identities.

The first results are from Shapiro-Wilk tests, which checked if data from the two instruments were normally distributed. Results from these tests helped the researcher to decide whether to use parametric or non-parametric tests for comparing participants' pre and post scores. The second set of results are from (1) Wilcoxon signed rank tests comparing participants' pre and post EIDS (academic identity and engineering career identity) scores and (2) a paired samples t-test comparing participants' mean pre and post S-STEM scores. These two results are each followed by Cohen's *d* effect size to measure the effect size of the intervention on the dependent variables, and Cronbach's alpha values to measure the reliability of each subscale used in this study.

Normality Test

Table 2 shows results from the Shapiro-Wilk test conducted using data from the (1) academic identity and (2) engineering career identity subscales of the EIDS.

Table 2: Shapiro-Wilk test for normality of the EIDS

Instrument	Subscale	Obs	W	V	z	Prob>z
EIDS	Academic identity	20	0.88	2.80	2.08	0.01874
	Engineering career identity	20	0.97	0.8	-0.45	0.67374

The researcher conducted a Shapiro-Wilk test to determine if paired differences between pre and post EIDS scores were normally distributed. Results indicated that data from the academic subscale were not normally distributed ($W = 0.88$, $p < 0.05$) while data from the engineering career subscale were normally distributed ($W = 0.96621$, $p > 0.05$). Because data from one of the subscales (academic identity) were not normally distributed, the researcher used a non-parametric test (in this case, the Wilcoxon signed-rank test) to compare participants' pre and post EIDS scores from the two subscales.

Table 3 shows results from the Shapiro-Wilk test conducted using data from the S-STEM.

Table 3: Shapiro-Wilk test for normality of the S-STEM

Instrument	Subscale	Obs	W	V	z	Prob>z
S-STEM	Engineering and technology	20	0.95	1.17	0.31	0.37834

The researcher conducted a Shapiro-Wilk test to determine if paired differences between pre and post S-STEM scores were normally distributed. Results from Table 3 show that data from the S-STEM were normally distributed ($W = 0.95$, $p > 0.05$). This allowed the researcher to compare participants' mean pre and post S-STEM scores using a parametric test, in this case the paired samples t-test.

<u>Research Question One</u>

This section presents results from the first research question: What is the impact of engaging elementary students in place-conscious engineering activities on their engineering identities? The section separately presents results from the academic and engineering career subscales of the EIDS. This question was guided by a null hypothesis (H_0) and an alternative hypothesis (H_1) as follows:

> H_0: There is no statistically significant increase in students' engineering identities after engaging in place-conscious engineering activities and

H_1: There is a statistically significant increase in students' engineering identities after engaging in place-conscious engineering activities.

Academic Subscale. Table 4 shows the results of a Wilcoxon signed rank test from the academic subscale of the EIDS. Out of the 20 paired observations, five yielded positive differences, three yielded negative differences, and 12 yielded no differences. Although results showed an increase in students' academic identities from pre to post, the increase was not statistically significant $z(19) = 0.49$, $p > 0.05$. The results did not support the study's alternative hypothesis. They suggest that students' participation in place-conscious engineering activities does not improve their academic identities.

Table 4: Wilcoxon signed rank test for elementary students' pre and post academic identities

Sign	Obs	Sum ranks	Expected
Positive	5	77.5	66
Negative	3	54.5	66
Zero	12	78	78
All	20	210	210

z = 0.49 df = 19 p = 0.7266

The researcher did not compute the effect size for this pre – post comparison because the difference between the pre and post was not statistically significant. Cronbach's alpha values for pre and post of the academic subscale of the EIDS (6 items) were 0.53 and 0.77, respectively. According to Sharma (2016), Cronbach's alpha values greater than or equal to 0.5 but less than 0.6 are poor, while those greater than or equal to 0.7 but less than 0.8 are acceptable. This means that the academic subscale of the EIDS measured students' engineering identities with poor and acceptable internal consistencies at the pre and post, respectively (Sharma, 2016).

Engineering Career Subscale. Table 5 shows the results of a Wilcoxon signed rank test from the engineering career subscale of the EIDS. Of the 20 paired observations, eight had positive differences, none had negative differences, and 12 had no differences. The results were consistent with the study's alternative hypothesis as indicated by a statistically significant increase $z(19) = 2.81$, $p<0.01$ in students' engineering career identities from pre to post. These results suggest that students' participation in place-conscious engineering activities improved their engineering career identities.

Table 5: Wilcoxon signed rank test for elementary students' pre and post engineering career identities

Sign	Obs	Sum ranks	Expected
Positive	8	132	66
Negative	0	0	66
Zero	12	78	78
All	20	210	210

z = 2.81 df = 19 p = 0.0078

The Cohen's *d* value for this pre – post comparison was 0.55, indicating a medium effect size (Mcleod, 2023). This means that on a scale of small, medium, or large, students' participation in place-conscious engineering activities had a medium effect size on their engineering career identities. Also, on a scale of small, medium, or large, the difference between students' pre and post engineering career identity scores was medium. Cronbach's reliability coefficients for the pre and post of the engineering career subscale (10 items) of the EIDS were 0.79 and 0.75, respectively. These values fall within the acceptable range of Cronbach's alpha values (Sharma, 2016). This means that the engineering career subscale of the EIDS measured students' engineering identities with an acceptable internal consistency (Sharma, 2016).

Research Question Two

This section presents results from the second research question: What is the impact of engaging elementary students in place-conscious engineering activities on their attitudes towards engineering and technology? To answer this question, the researcher generated a null hypothesis (H_0) and alternative hypothesis (H_1) as follows:

> H_0: There is no statistically significant increase in students' attitudes towards engineering and technology after engaging in place-conscious engineering activities and

> H_1: There is a statistically significant increase in students' attitudes towards engineering and technology after engaging in place-conscious engineering activities.

Table 6 shows the results of a paired samples t-test from the engineering and technology subscale of the S-STEM. Consistent with the study's alternative hypothesis, results from the pre (M = 3.56, SD = 0.82) and post (M = 4, SD = 0.77) indicate that students' participation in place-conscious engineering activities significantly improved their attitudes towards engineering and technology $t\ (19) = 3.12$, $p < 0.01$.

Table 6: Paired samples t-test for elementary students' pre and post S-STEM

Variable	Obs	Mean	Std. err.	Std. dev.	[95% conf. interval]	
Post S-STEM	20	4	0.17	0.77	3.64	4.36
Pre S-STEM	20	3.56	0.18	0.82	3.18	3.94

t=3.12 df=19 p = 0.0028

As measured by Cohen's *d*, the effect size of the paired samples t-test was 0.73, indicating a medium effect size (Mcleod, 2023). This suggests that on a scale of small, medium, or large, place-conscious engineering activities had a medium impact on students' engineering career identities. Cronbach's reliability values for the pre and post of the S-STEM's engineering and technology subscale (9 items) were 0.86 and 0.89, respectively. Sharma (2016) classifies Cronbach's alpha values greater than or equal to 0.8 but less than 0.9 as good. The S-STEM's engineering and technology subscale measured students' pre and post engineering identities with good internal consistency (Sharma, 2016).

Qualitative Results

Research Question Three

This section presents results from the third research question: What do students' descriptions of their engagement with engineering activities reveal about their engineering identities and attitudes towards engineering and technology? The researcher used data from focus group interviews to answer this research question. The researcher analyzed the data using thematic analysis, which uncovered themes from students' descriptions of their engagement with place-conscious engineering activities. The purpose of this analysis was to provide nuanced explanations for trends observed in the quantitative results. In this section, results focus on summarizing emerging themes (see Table 7) and then describing how each theme connects to students' engineering identities and attitudes towards engineering. Themes are presented in the order of the researcher's perceived importance. The researcher determined the importance of these themes based on the prevalence of codes within each theme and their level of connection to students' engineering identities and/or attitudes towards engineering and technology. Themes with a greater number of codes, higher frequency of each code, and stronger connections to the dependent variables were considered more important than those with fewer codes, lower frequency of each code, and weaker connections to the dependent variables.

Summary of Themes. This section provides an overview of emerging themes, presented as a table. Specifically, Table 7 shows the six themes identified from students' interview data, their corresponding codes and examples of interview data fitting the codes.

Table 7: Summary of emerging themes, their corresponding codes and example data

Themes	Codes	Example of data fitting the codes
1. Hands-on engineering activities	• hands-on	• "I like building air filters" • "we made the air filters" • "we had to make the little models, those have houses and everything" • "Eyes were fun. So, we made like these little um things that "had like this ah cadnium? Cadnium, and like, I think she was…" • "Ah we did a stand that had to hold a dinosaur" • "we did the um, that whoever can build the highest tower"
2. Societal utility of Engineering	• societal utility	• "There was a big fire and there was a bunch of smoke in the air. It made it hard to breath for people. So, we made air filters for the Denton (name of town) people." • "… and then after that, once we got them all right, then we "gave them away to the Denton people so they can like use their air filters"
	• place	• "Um we got to help people in Denton" • "In Denton there was the fire, like we did, it was engineering… but it's also solving a problem for them and helping them out" • "[engineers] solve problems in neighborhoods"
3. Learning from failure and engagement in collaboration	• Learning from failure	• "we had a lot of mistakes like the cardboard wasn't on the ground or the cardboard wasn't in the right place, the air filters weren't in the right place, and then like the fan wasn't in the right place, and we had to like retry and retry until we got it right" • "we made a lot of mistakes and retried until we got it right testing different ideas, and generating new ideas"
	• Collaboration	"Me and BX13 were a team and like, we had many ideas, but we've tried them, and they didn't work. So, then we had ah, to think of another idea…"

Table 7 continued.

4. Satisfaction from learning engineering	• Satisfaction	• Interviewer: "is there any engineering product you wish that you would get to do that you haven't done yet?" Students: BX12: "No" BX13: "Not really" BX17: "I don't really know any projects"
5. Positive perceptions of engineers as highly skilled	• Engineering skill	• "But I would say like engineers do more than just like little things like they build cars, they find out like big problems they do a lot of things." • "They can do anything from making a car fly to making a bike that flies" • "Yeah, they can do anything"
	• Engineering helpful	• "they [engineers] can do anything from making a car fly to making a bike that flies" • "they [engineers] do big stuff, and they help out the world" • "[engineers] solve problems in neighborhoods."
6. Engineering career aspirations	• Positive engineering career aspiration	• "yes" • "yep" • "definitely" • "kind of"
	• Neutral engineering career aspiration	• "Pilot [believes it involves engineering], or maybe a lawyer" • "not sure (maybe and engineer or accountant) or a mix of engineering and food) neutral"
	• Negative engineering career aspiration	• "no (professional baseball player)" • "no" • "probably not"

The following is a list of themes that emerged from data analysis, their descriptions, and explanations of data supporting these themes. In each theme, the initial paragraph consists of the researcher's theme descriptions, providing an overview and context for that specific theme.

Theme 1: Hands-On Engineering Activities. This theme focuses on describing how students experienced hands-on engineering activities. It also describes how students evaluated their feelings about participating in hands-on engineering activities and how this participation impacted their understanding of engineering.

Students noted that they completed more engineering activities during that particular year than in previous years. For example, BX9 stated, "[We] did a lot more engineering things [this year]." Students noted that they designed and built air filters, jumping devices, model houses, and dinosaur stands, all of which involved hands-on engineering. They also stated that completing hands-on engineering activities during that year was fun. For example, BX6 stated, "I like how [Emma, their teacher] does a lot of hands-on activities." Then, BX5 responded, "yeah" and BX6 added, "it's really fun." To add to the discussion, BX10 specifically stated that engineering during that year was fun because it involved "build[ing] new things," which is hands-on oriented. This exchange suggests that students had fun participating in hands-on engineering activities.

Overall, students engaged in hands-on engineering activities and claimed that they had fun completing them. The hands-on nature of these activities could have contributed to the students' change in their engineering identities and attitudes toward engineering and technology.

Theme 2: Societal Utility of Engineering. This theme describes how students connected engineering to society, especially within their local environments. Specifically, the theme focuses on how students perceived the purpose of engineering in society, their feelings about the societal utility of engineering, and their experiences participating in engineering within their local communities.

Students mentioned that engineering that year was fun because it engaged them in engineering activities (i.e., building air filters) that helped people instead of mere projects. Throughout the interview sessions, students connected engineers' work to society and consistently positioned helping people at the center of engineering. They mentioned that the purpose of engineering was to help people. In describing what engineers do, BX20 stated, "[engineers] solve problems in neighborhoods," and other students made similar statements. For example, BX4 said, "oh they, they find your problem and then all and then they find a solution to solve the problem by building something to help them." Then, BX23 responded, "just um, if people are having trouble with um, for example, when um, someone's arm or leg is amputated, and they can't really walk, people [engineers] make prosthetics that can um, help them walk or grab stuff easier." In these statements, students positioned engineering as a tool for solving problems and helping people. This view resurfaced when students discussed the process they engaged in when building air filters.

When the discussion focused on air filters, students stated that the purpose of building air filters was to help the local people. They further indicated that they were happy that they built the air filters because they helped people. For example, BX17 commented, "I felt like I just did something for the world", then BX16 responded, "yeah" and BX17 further added, "I felt like I was a superhero saving the world." Other students made similar statements. For example, BX18 stated, "it was something really good," and BX16 mentioned, "It really felt good". Another student, BX15, justified feeling happy about making air filters by stating, "because we were helping people in need." When asked if helping people was part of engineering, students responded affirmatively, reiterating their perceptions of engineering as a tool for helping people.

Students' connection of engineering to helping people was also evident in their description of what they aspired to do if they became engineers. For example, BX20 stated, "first, [I would] go around like my neighborhood and ask if anybody has like a problem that they need to solve. I might also like gather some of my friends that wanted to be an engineer and like, make a miniature company". While BX20 was open to identifying and addressing different local engineering problems, other students planned to address specific engineering problems. These included building flying cars and teleporters for quicker transport, faster spaceships for NASA, phones with better cameras, and solving problems related to natural disasters. As evidenced by the information in this paragraph, students purposively aspired to engage in projects that help people.

Overall, this theme provided information suggesting that students had fun developing engineering solutions that helped people, viewed helping people as an integral part of engineering, developed a better understanding of engineers' work due to participation in that year's engineering activities, and considered using engineering to help people if they became engineers.

Theme 3: Learning from Failure and Engagement in Collaboration. This theme deals with students' experiences with (1) learning from failure and (2) completing engineering tasks through collaborative efforts – two of the qualities of authentic engineering learning (Bosman & Fernhaber, 2018). In this theme, collaboration encompassed students working together to complete engineering tasks. Learning from failure encompassed students solving problems to complete a larger engineering goal and iteratively modifying their designs and products to meet desired requirements.

The engineering activities students completed incorporated essential attributes of authentic engineering, such as learning from failure and working collaboratively. Regarding learning from failure, students reported making many mistakes and iteratively finding solutions to correct them, especially during the designing and building of air filters. BX5 stated, “We had a lot of mistakes like the cardboard wasn’t on the ground or the cardboard wasn’t in the right place, the air filters weren’t in the right place, and then like the fan wasn’t in the right place, and we had to like retry and retry until we got it right, and it was really fun.” BX7 added, “we had many ideas, but we’ve tried them, and they didn't work. So, then we had ah, to think of another idea”. BX6 commented, “Yeah, we had to find the problem, and then so you had to test it, find the problem and then improve it.” Despite facing challenges, students were persistent in solving problems and improving their designs while building air filters. One student, BX16, stated, “I like building the air filters coz most of the time, if you messed up, you’d have to rebuild everything”. BX5 described the process of making mistakes and figuring out solutions as “really fun.” BX19 stated, “[We learned that] sometimes you can make mistakes…” As evidenced by these statements, students seemed unworried about the failure of their engineering designs. Instead, they reported having fun making mistakes and finding solutions to correct them - they seemed to understand that failure is part of engineering. Making mistakes and iteratively correcting them to improve engineering designs is typical of learning from failure. Learning from failure is integral to engineering and an essential aspect of authentic engineering. Considering this connection, fun from learning from failure could suggest identification with engineering and positive attitudes towards learning from failure and engineering in general.

Regarding collaboration, students agreed that they completed some engineering activities in groups, and the data suggests that students valued teamwork. For example, students explained that they developed flood prevention plans collaboratively and received feedback from their peers, which they used to improve their designs. BX7 stated, “Whenever we had the tiny levees we made ah, we went around and gave notes [feedback] to the teams, other teams…” BX5 added, “and kind of helped make the plans better... We also didn't have to argue as a group.” then BX responded, “Oh yeah,” and BX5 added, “So everybody got to put in their opinion.” BX7 continued, “Because like yeah, I know some people have some good ideas, but like, if you don't listen to other people's ideas, then you won't know if their idea is better than yours, or not like better than yours, or like, that will work better.” When talking about an activity students completed, BX7 said “me and BX13 were a team”, further indicating that students worked in teams. When students were asked what they would do if they became engineers, BX20 stated, “I might also like, gather some of my friends that wanted to be an engineer and like, make a miniature company.” These statements suggest that students valued and respected their peers’ ideas and inputs because they improved their designs. This is also evidenced by students’ affirmative response to the question, “Is that [working in teams] important?” This paragraph suggests that students valued teamwork in completing engineering tasks, which could influence their outlook on the engineering field.

Overall, the activities students completed that year allowed them to learn from failure and collaborate with their peers. This theme suggested that students understood that failure was normal in engineering, had fun learning from failure, were persistent in solving the problems they encountered when building air filters, and valued their peers' contributions when completing engineering tasks.

Theme 4: Satisfaction from Learning Engineering. This theme deals with information related to students' level of satisfaction with the engineering activities they completed during the year they participated in this study. Satisfaction was assessed using data indicating whether students had complaints about the engineering activities they completed, expressed a desire to continue learning engineering in a manner similar to how they learned it during that year, and wished for the upcoming fourth graders to experience engineering learning in a manner similar to their own.

Students expressed satisfaction with the engineering activities they completed that year. When questioned about whether there were any engineering activities they wished they had completed during the same year, most students responded negatively, suggesting that they were satisfied with the engineering activities they had completed. Also, students expressed interest in continuing to learn engineering when they go to middle school. For example, BX14 stated, "I'm excited for next year because I think we're gonna do more [engineering]", suggesting that the student aspired to continue learning engineering. Another piece of data supporting this observation emerged when the interviewer asked, "…and so next year [Emma] is gonna have new students. Do you…" and then, BX12 interrupted the interviewer by responding, "I'm sad about it, I want to stay". These statements suggested that students looked forward to continuing to learn engineering in higher grades, which could result from satisfaction from learning engineering during that year.

When asked, students advocated for Emma to use a similar approach to teach the upcoming fourth graders engineering. For example, BX18 responded with, “Yes, because it’s a really fun activity [engineering] to do,” and added, “And it teaches them that engineering is actually really good.” Students justified this position by stating that learning engineering taught by Emma was fun, because of the extensive use of hands-on learning and connecting engineering to local challenges. In justifying their position, students added that if upcoming fourth graders learned engineering with Emma, they could potentially understand that engineering is not only about building simple things but also about tackling complex problems. BX7 said, “Kids will start to realize that it's [engineering] kind of bigger than what they think.” Students also believed the fourth graders would better understand engineering and how engineers help people. BX8 stated, "Yeah, this [engineering taught by Emma] is getting kids to recognize what engineers do and like how engineers help. They don't just like mess around at their job.” Students’ justifications of their desire for Emma to teach fourth graders engineering could indicate that they were satisfied with learning engineering taught by Emma.

This theme described several observations suggesting that students were satisfied with the engineering activities they completed that year. These included: (1) students reported no engineering activities they wished they had completed. (2) students desired to continue learning engineering in higher grades, and (3) they desired the next fourth graders to experience engineering learning as they did. Students’ satisfaction with learning engineering and willingness to continue learning engineering could indicate positive engineering identities and attitudes towards engineering.

Theme 5: Positive Perceptions of Engineers as Highly Skilled. This theme describes how students perceive engineers regarding their capabilities and usefulness to society. This theme used data that revealed students' views of engineers' capabilities to complete complex tasks and the impact of completing such tasks on the well-being of society.

Students' perceptions of engineers as highly skilled surfaced when discussing what engineers do. While students associated engineering with rudimentary actions such as "building" and "fixing" things, they also connected engineering to more complex actions such as "designing," "testing," "improving," and identifying and solving problems to help people. Students described engineers as very skilled people capable of completing complex engineering tasks. BX6 commented that "engineers do more than just like little things like they build cars; they find out like big problems; they do a lot of things." BX7 said, "They [engineers] can do anything from making a car fly to making a bike that flies," and then BX6 responded, "Yeah, they can do anything." In describing engineers' work, BX6 mentioned that "[engineers] don't just just go to their job and get paid for walking around and then mixing random stuff." BX7 stated that "[engineers] get to design stuff, and it's actually really fun," and BX8 responded, "So yeah, pretty fun." Students constantly linked engineers' work to helping people. BX7 mentioned that "they [engineers] do big stuff, and they help out the world," and BX20 commented that "[engineers] solve problems in neighborhoods."

Students' perceptions of engineers as highly skilled and helpful people resurfaced when they discussed goals they would pursue if they became engineers. They mentioned things such as designing and building cars (including flying cars) to help people get around, building faster spaceships for NASA, teleporters for quicker transport, computers, phones, and TVs, and building improved space suits. Other students said they would make prosthetics to help people and animals with missing limbs, solve natural disasters like tornadoes, and make food for hungry people. Some of the goals students planned to achieve through engineering (i.e., building teleporters and faster spaceships) were relatively complex, reaffirming students' perceptions of engineers as highly skilled.

Theme 6: Engineering Career Aspirations. This theme deals with data about students' engineering career aspirations. This theme describes how students directly responded to a question asking them to state if they considered becoming engineers in the future. A comparison of positive, neutral, and negative responses informed the evaluation of students' engineering career aspirations described in this theme.

When asked if they considered pursuing engineering careers, some students mentioned wanting to become engineers, some were unsure, others showed no interest, and some switched between different career options. The researcher classified students' responses to this question as positive, neutral, and negative. Frequency comparisons between these categories indicated that the positive response category had the most responses, followed by the neutral and negative categories. This could indicate that students who provided positive responses had positive engineering identities.

Research Question Four – Mixing of Quantitative and Qualitative Data

This section presents results from the fourth research question: How do the findings from the qualitative interview support the findings from the quantitative survey? To address this question, the researcher presents quantitative findings about students' academic identity, engineering career identity, and attitudes towards engineering and technology. Then, the researcher identifies and presents qualitative data relevant to these constructs and discusses how they either support or not support the quantitative. Finally, the researcher presents one overarching explanation to answer the research questions.

Engineering Identity

This section presents findings on students' engineering identities. The section has two sub-sections, one focusing on students' academic identities and the other on their engineering career identities.

Students' Academic Identities. Academic identity relates to students' "self-beliefs in who they are as students" (Capobianco et al., 2012, p. 703). According to (Capobianco et al., 2012), some of the indicators of positive academic identities include students' engagement in their school work and ability to work well in school groups. Quantitative results from the academic subscale of the EIDS showed increased students' academic identities from pre to post. However, this increase was not statistically significant $z(19) = 0.49$, $p>0.05$, suggesting that students' participation in place-conscious engineering activities did not improve their academic identities. However, solely relying on this conclusion to draw unbiased inferences about students' academic identities could be challenging. Firstly, the EIDS's academic subscale measured students pre academic identities with poor internal consistency, which could have affected these quantitative results, and secondly, items from EIDS's academic subscale had little to no connection with place-conscious engineering. Based on these reasons, quantitative findings about students' academic identities were inconclusive.

However, an examination of qualitative data provided evidence suggesting that participating in place-conscious engineering activities improved students' academic identities. For example, qualitative data suggested that students were willing to continue learning engineering. When the interviewer asked students if they wanted to learn engineering in higher grades, they responded affirmatively. In addition, BX14 stated, "I'm excited for next year because I think we're gonna do more [engineering]," suggesting that students were interested in continuing to engage with their schoolwork. Desires to continue engaging with schoolwork can indicate positive academic identities.

Another indicator of students' positive academic identities is that they collaboratively worked in small groups to complete academic tasks. For example, BX5 said, "[collaboration] kind of helped make the plans better, and like other people's opinions that way. We also didn't have to argue as a group with like one opinion," suggesting that students valued and respected peers' opinions. Then, the interviewer asked, "Do you think that is important?" and BX7 responded affirmatively, "Cause like yeah, I know some people have some good ideas, but like, if you don't listen to other people's ideas, then you won't know if their idea is better than yours, or not like better than yours, or like, that will work better," suggesting that students valued peer feedback. The statement from BX7 further reinforces the claim that students worked well with peers, which further supports the claim that students developed positive academic identities.

Table 8 shows items from the academic subscale of the EIDS, along with examples of corresponding qualitative data and information about whether qualitative data supports quantitative data. Available qualitative findings suggested that students' academic identities improved after participating in place-conscious engineering. In other words, participation in place-conscious engineering activities improved students' academic identities.

Table 8: Sample qualitative data matching items from the EIDS's academic subscale

	Item from the academic subscale of the EIDS	Example of qualitative data fitting item
1	I do my school work as well as my classmates	BX14: "I'm excited for next year because I think we're gonna do more [engineering]"
2	I am good at solving problems in mathematics	Not Applicable
3	I use computers as well as my classmates	Not Applicable
4	I am good at working with others in small groups	BX5: "[collaboration] kind of helped make the plans better, and like other people's opinions that way. We also didn't have to argue as a group with like one opinion,"
5	I like being a student at my school	Not Applicable
6	I make friends easily at my school	Not Applicable

<u>Students' Engineering Career Identities.</u> Engineering career identity relates to students' "self-goals, aims, or objectives of becoming an engineer" (Capobianco et al., 2012, p. 703). Results from the pre and post of the engineering career subscale of the EIDS indicated a statistically significant increase $z(19) = 2.81$, $p<0.01$ in students' engineering career identities. The results suggested that students' participation in place-conscious engineering activities positively influenced their engineering career identities. Results also showed that the EIDS's engineering career subscale measured students' engineering career identities with an acceptable internal consistency.

The qualitative results provided evidence supporting students' development of engineering career identities. Firstly, students indicated that they strongly desired to continue learning engineering. When the interviewer asked if students wanted to learn engineering in middle school, students responded affirmatively. BX14 said, "I'm excited for next year because I think we're gonna do more [engineering]." Inclination to engage with engineering could indicate favorable engineering career identities. Also, the greatest proportion of students considered pursuing engineering careers in the future. Students' desires to pursue engineering careers could indicate desires to continue engaging with engineering and, consequently, positive engineering career identities.

Secondly, students perceived engineers as skilled individuals capable of completing complex tasks and solving some of society's problems. For example, BX7 said, "They [engineers] can do anything from making a car fly to making a bike that flies," and then BX6 responded, "Yeah, they can do anything." And later added, "Engineers do more than just like little things like they build cars; they find out like big problems, they do a lot of things." Statements from BX6 and BX7 suggest that engineers are skilled – a positive perception of engineers, which could indicate positive engineering career identities. Thirdly, students appeared happy about participating in engineering that addressed local problems by building air filters. For example, BX17 said, "I felt like I just did something for the world," and later added, "I felt like I was a superhero saving the world." As evidenced by statements from BX17, students seemed inclined towards addressing problems through engineering. This inclination could indicate students' positive engineering career identities.

Table 9 shows the 10 items of the EIDS's engineering career subscale, examples of corresponding qualitative data, and information about whether qualitative data supported quantitative data. Available qualitative data supported all quantitative items of the EIDS's engineering career subscale. Collectively, quantitative and qualitative results provide evidence that students' participation in place-conscious engineering activities improved their engineering career identities.

Table 9: Sample qualitative data matching items from the EIDS career identity subscale

	Item from the Engineering career subscale of the EIDS	Example of qualitative data fitting item
1	Engineers solve problems that help people	BX20: "[engineers] solve problems in neighborhoods"
2	Engineers work in teams	BX20: "[If I were an engineer] I might also like, gather some of my friends that wanted to be an engineer and like, make a miniature company."
3	Engineers design everything around us	BX9 "[Engineers] design cars and build them."
4	There is more than one type of engineer	BX5 "And there's a lot of types of engineers,"
5	Engineers use mathematics	Interviewer: "Do you think engineers use math in what they do?" BX23: "Yeah." BX2 "Oh yeah!"
6	Engineers use science	BX7 "Engineers] figure out like how much pressure can go into a car tire to make sure it doesn't pop on the road when it hits a little pebble"
7	Engineers are creative	BX7 "[Engineers] can do anything from making a car fly to making a bike that flies"
8	When I grow up I want to be an engineer	Interviewer: Do you think you'd be interested in being engineers when you grew up?" BX 6: "Yeah."
9	When I grow up I want to solve problems that help people	BX22: "[If I were an engineer] I would probably I would probably get together with some other engineers and see. If the people have problems, we could at least try to solve for people to make it make them happier."
10	When I grow up I want to work on a team with engineers	BX20: "[If I were an engineer] I might also, like, gather some of my friends that wanted to be an engineer and, like, make a miniature company."

<u>Students' Attitudes Towards Engineering and Technology.</u> Pre ($M = 3.56$, $SD = 0.82$) and post ($M = 4$, $SD = 0.77$) results from the S-STEM showed a statistically significant increase in students' attitudes towards engineering and technology t (19) =3.1203, $p < 0.01$. The results suggest that place-conscious engineering activities significantly improved students' attitudes towards engineering and technology. The S-STEM measured students' attitudes towards engineering and technology with a good internal consistency.

Qualitative results supported these quantitative results. Firstly, qualitative results suggested that students enjoyed engaging in place-conscious engineering activities. For example, when the interviewer asked students to talk about the engineering activities they completed, students described these activities as “fun.” Students' perceptions of these engineering activities as fun could suggest that students had positive attitudes towards engineering. Secondly, students indicated that they desired to continue learning engineering. This could indicate students’ positive attitudes towards engineering and technology because individuals tend to engage in actions, they have positive attitudes towards. Thirdly, results suggest that students seemed happy that they completed engineering activities that allowed them to help people. For example, BX18 said, “It was something really good,” BX16 said, “It really felt good,” and student BX15 justified, “because we were helping people in need.” Students’ satisfaction and happiness in engaging with engineering can be an indicator of students’ positive attitudes towards engineering.

Table 10 presents items from the S-STEM’s engineering and technology subscale, examples of corresponding qualitative data, and whether qualitative data supported quantitative data. The findings indicate that the qualitative data corroborated the quantitative results obtained from the S-STEM. Together, the quantitative and qualitative findings suggest that students' engagement in place-conscious engineering activities positively improved their attitudes towards engineering.

Table 10: Sample qualitative data matching items from the S-STEM's engineering and technology subscale

	Item from the engineering technology subscale of the S-STEM	Example of qualitative data fitting item
1	I like to imagine creating new products.	Interviewer: "So you said it (engineering) was fun. What makes it fun?" BX10: "Getting to build new things"
2	If I learn engineering, then I can improve things that people use every day.	BX23: "I became an engineer, I'd probably make like inventions that would help, like, people."
3	I am good at building and fixing things.	Not applicable
4	I am interested in what makes machines work.	Not applicable
5	Designing products or structures will be important for my future work.	Interviewer: "So imagine it is 20 years in the future, and you have gone to school and become an engineer? What do you think you would do?" BX9: "Design cars and build them." BX11: "Ah, I would do the same thing."
6	I am curious about how electronics work.	"Hopefully, we can build more things and not really like, like, more of the fan things." Interviewer: "So you want to make things that have motors or electronics or something like that?" BX14: "Yeah"
7	I would like to use creativity and innovation in my future work.	BX23: "I became an engineer, I'd probably make like inventions that would help like, people."
8	Knowing how to use math and science together will allow me to invent useful things.	Interviewer: "So you do use math during engineering?" BX23: "Yeah"
9	I believe I can be successful in a career in engineering.	Interviewer: "So have you ever thought about being an engineer? Is that something you'd be interested in?" BX1: "Yes", BX23: "Definitely", BX4: "Kind of"

Chapter Summary

This chapter presented findings from the present explanatory sequential mixed methods study. Quantitative and qualitative results on students' academic identities were inconclusive. The researcher highlighted weaknesses in the instrument's reliability in measuring students' academic identities. Quantitative and qualitative data collectively suggested that students' engineering career identities and attitudes towards engineering and technology improved after participating in place-conscious engineering activities. In all cases, qualitative results adequately supported quantitative results. In the next chapter, the researcher thoroughly analyzed these results by comparing them with relevant literature to provide deeper insights into their implications.

CHAPTER FIVE

DISCUSSION

Introduction

This study investigated the effects of students' participation in place-conscious engineering activities on their (1) engineering identities and (2) attitudes towards engineering and technology. First, this chapter briefly discusses background information about the study's participants, intervention, data collection, and analysis to remind readers about these aspects. It then delves into the present study's findings, interpretations, implications, recommendations, and conclusions. Regarding discussing findings and their interpretations, this chapter addresses each of the four research questions separately. The following section is an overview of this study's background information.

Brief Background

Participants of this study included 20 fourth-grade students enrolled in an elementary school in southwest Montana. As an intervention, these students participated in a year-long science curriculum incorporating two major place-conscious engineering activities: (1) building air filters for local fire survivors and (2) designing flood prevention strategies for a nearby river. This section presents a concise overview of the study's intervention and the data collection and analysis processes.

During the air filter activity, students read news stories about a local wildfire that left residents of a nearby town breathing smoke-polluted, unhealthy air. Students brainstormed solutions to solve the problem and designed and built box fan air filters. Students tested their box fan air filters and discussed with Emma (their teacher) why some designs worked, and others failed. Then, students improved their designs until their products met specific criteria. Finally, two volunteers transported the finished products to the affected community. During the flood prevention activity, students learned how floods occur and possible engineering solutions to minimize their impact. Students learned how ice jams cause flooding. Then, a local floodplain engineer visited the class and used flood simulation software to demonstrate how floods would affect a nearby town and discuss remediation strategies. Students built a model floodplain, which they later used to simulate flooding under different rain intensities. Then, they used chart-paper to design flood prevention strategies to minimize the effects of floods from a nearby river.

Students completed pre and post surveys of the upper elementary (fourth – fifth graders) version of the S-STEM (Friday Institute for Educational Innovation, 2012). The S-STEM has six subscales: science, engineering and technology, mathematics, 21^{st}-century skills, your future, and about yourself. This study only used the nine items under the engineering and technology subscale of the S-STEM because they aligned with this study's focus - measuring students' attitudes toward engineering and technology. Students also completed pre and post surveys of the EIDS (Capobianco et al., 2012). The EIDS consists of two subscales: academic identity and engineering career identity. This study used both subscales to measure students' engineering identities. Finally, students participated in semi-structured focus group interviews to complement quantitative data from the S-STEM and EIDS. The interview focused on three main questions: (1) "Tell me about the engineering activities you did in class this year", (2) "what do you think engineers do for their jobs?" and (3) "would you want to be an engineer when you grow up? why or why not?"

The researcher analyzed quantitative data from the S-STEM and EIDS using STATA version 18. First, the researcher removed incomplete observations from the S-STEM and EIDS. Then, the researcher conducted Shapiro-Wilk tests to determine if data from the S-STEM and EIDS were normally distributed. The researcher compared students' pre and post scores from the S-STEM using a paired samples t-test because the data were normally distributed, and students' pre and post scores from the EIDS using Wilcoxon signed-rank tests because the data were not normally distributed. The researcher also computed Cohen's *d* values to determine the intervention's effect size on the dependent variables and Cronbach's alpha values to determine the reliability of the S-STEM and EIDS.

The researcher analyzed qualitative interview data using Braun and Clarke's (2006) six-step approach to thematic analysis involving: (1) familiarizing yourself with your data - recording the data through transcription as needed, carefully reviewing the data by repeatedly reading it and jotting down initial thoughts and ideas, (2) generating initial codes - systematically identifying interesting data elements and assigning codes to them across the entire dataset while collecting relevant data for each code, (3) searching for themes - compiling related codes into possible themes and grouping all relevant data for each potential theme, (4) reviewing themes - verifying the validity of themes by examining their relationship to the coded extracts and the entire dataset and creating a thematic 'map' of the analysis, (5) defining and naming themes - continuing to analyze the data to clarify each theme's details and refine the overall narrative that the analysis presents while developing precise definitions and labels for each theme, and (6) producing the report - selecting vivid and convincing examples from the data, conducting a final analysis of the chosen extracts, linking the analysis back to the research question and relevant literature, and producing a scholarly report that summarizes the findings of the analysis. Finally, the researcher examined how findings from the qualitative interviews explained findings from the quantitative surveys.

Research Question One

This section discusses how the researcher addressed the first research question: What is the impact of engaging elementary students in place-conscious engineering activities on their engineering identities? The section separately discusses the findings from the academic and engineering career subscales of the EIDS.

Academic Subscale.

A Wilcoxon signed rank test showed no statistically significant difference between students' academic identities before and after participating in place-conscious engineering activities $z(19)=0.49$, $p>0.05$. This result suggests that EIDS did not detect a significant increase in students' academic identities. While these findings may be surprising, given students' active engagement in place-conscious engineering activities, several reasons could explain this outcome.

First, this study exposed elementary students to place-conscious engineering activities as an intervention. However, the six items in the academic subscale of the EIDS had little to no connection to engineering and place consciousness. The six items are (1) I do my school work as well as my classmates, (2) I am good at solving problems in mathematics, (3) I use computers as well as my classmates, (4) I am good at working with others in small groups, (5) I like being a student at my school, and (6) I make friends easy at my school. These items focus on general aspects of students' academic identities, not on engineering. Capobianco et al. (2012) state that the academic subscale measures students' "self-beliefs in who they are as students" (p. 703). Considering the lack of adequate connection between the intervention and these items, it is unsurprising that findings suggested that the EIDS did not detect a statistically significant increase in students' academic identities. It would be necessary for future studies to develop an alternative instrument that better measures students' academic identities, with a specific focus of better aligning such an instrument with engineering.

Secondly, the EIDS measured students' pre academic identities with a poor internal consistency reliability ($\alpha = 0.53$) and the post with an acceptable internal consistency reliability ($\alpha = 0.77$) (Sharma, 2016). The low Cronbach's alpha value recorded at the pre could have affected the accuracy of collected data and skewed findings from this subscale. This observation is not new. In a study that validated the EIDS, Capobianco et al. (2012) found a low Cronbach's alpha value ($\alpha = 0.58$) for the academic subscale of the EIDS. The study concluded that with a low Cronbach's alpha value of 0.58, "item performance will not differ systematically for students with low and high total scores" (Capobianco et al., 2012, p. 709). Considering these factors, the lack of statistically significant results may stem from the instrument's poor internal consistency.

Based on the explanations in the previous two paragraphs, findings may suggest that the EIDS did not detect changes in students' academic identities because of (1) the disconnect between the intervention and academic subscale of the EIDS, (2) the instruments' ineffectiveness in distinguishing between students with low and high academic identities, or (3) a combination of these two factors. Considering these challenges, making objective and unbiased conclusions about the students' academic identity development from this quantitative analysis is challenging. However, qualitative data provided evidence suggesting that students' participation in place-conscious engineering activities improved their academic identities. For example, students indicated a strong desire to continue learning engineering in their next grades. For example, the interviewer asked, "Do you hope to have engineering there [in middle school]?" Then, BX9, BX10, and BX11 all responded, "Yeah". This meant that students wanted to continue engaging with their academic work in the future. In fact, qualitative data showed that all students who responded to this question provided affirmative responses, providing further support for this claim. In a separate instance, the interviewer said "And so next year Emma is gonna have new students. Do you…" Then, BX12 interrupted and said, "I'm sad about it, I want to stay," indicating that the student wanted to continue engaging with their academic work. BX12's statement provided further evidence that students wanted to continue doing their academic work. Students' desire to engage with their academic work is an indicator of positive academic identity (Capobianco et al., 2012).

Aside from that, when students built air filters and flood prevention strategies, they completed these tasks collaboratives in small groups. Students' descriptions of these tasks suggested that they leveraged their peers' insight and contributions to complete the tasks. For example, BX5 said, "[Collaboration] kind of helped make the plans better, and like other people's opinions that way. We also didn't have to argue as a group with like one opinion." This statement suggests that students valued collaboration - they recognized and used their peers' inputs for making their plans better. BX5 went further to say, "So everybody got to put in their opinion," further supporting the claim that students worked collaboratively and valued the contributions their peers made. According to Capobianco et al. (2012), students working well in small groups is an indicator of positive academic identities.

In summary, while it was challenging to draw unbiased conclusions about students' academic identities from quantitative data, qualitative data provided evidence suggesting that students' academic identities improved after participating in place-conscious engineering activities. Interpreted together, the two data types suggest that students' academic identities improved as a result of participating in place conscious engineering activities.

Engineering Career Subscale.

A Wilcoxon signed rank test indicated that students' engagement in place-conscious engineering activities significantly improved their engineering career identities $z(19) = 2.81$, $p<0.01$. With a Cohen's *d* effect size of 0.55, the intervention had a medium effect size on students' engineering career identities (Mcleod, 2023; Sullivan & Feinn, 2012). These results suggest that students' increased engineering career identities result from participating in place-conscious engineering activities rather than random chance (Dahiru, 2008). According to Capobianco et al. (2012), engineering career identity relates to "children's self-goals, aims, or objectives of becoming an engineer" (Capobianco et al., 2012, p. 703). Therefore, an increase in students' engineering career identities could indicate that students experienced increased desires to become engineers. Students' engagement in place-conscious engineering activities, such as building air filters for fire survivors in a nearby town and designing flood prevention strategies for a nearby river, contributed to this change. The rest of this section discusses specific aspects of the intervention that could explain these quantitative results and supporting qualitative data.

Connecting Classroom Engineering to Students' Place. One of the factors that could have contributed to students' increased engineering career identities is participating in engineering activities that connect classroom engineering to issues within students' communities. Literature shows that place-conscious curricula bridge local engineering issues and formal school engineering knowledge (Avery, 2013; Buxton, 2010; Johnson et al., 2009; Lee et al., 2012). Thus, place-conscious activities such as building air filters for fire survivors living in a nearby town and designing flood prevention strategies for a nearby river could have allowed students to see the connection between classroom engineering and local community issues. This aligns with qualitative observations indicating that students linked classroom engineering with local community challenges and recognized the impact of engineering on society. For example, BX12 said, "I used to think all engineers just built, built things. Now I know they build things to help people," to which BX14 responded, "Yeah." Statements by BX12 and BX14 suggest that students understood that engineers build things but did not see the connection between building and helping people until they completed place-conscious engineering activities. In other words, qualitative data suggests that participating in place-conscious engineering allowed students to better understand engineers' work by connecting its purpose in society.

Qualitative data also suggested that after completing place-conscious engineering activities, students valued the role engineering plays in society. For example, students indicated that learning engineering was fun and wanted to continue learning it because it allowed them to help others. Similarly, when students discussed what they would do if they became engineers, they focused on engineering activities that addressed societal challenges related to transportation, space exploration, and food production. The claim that students valued engineering connected to their local community issues aligns with Brooke (2003) who indicates that students tend to perceive learning linked to their local contexts as valuable. It follows that students who find value in their engineering education are more likely to cultivate positive engineering identities (Westbrook, 2021). Based on Brooke (2003) and Westbrook (2021), one would conclude that anchoring classroom engineering learning to students' immediate surroundings can positively influence their engineering identities through perceptions of engineering as valuable. Therefore, in the present study, connecting students' engineering curricula to their local places could have contributed to their improved engineering career identities.

Engineering Design Process. Another factor that could have positively influenced students' development of their engineering career identities is their engagement with the engineering design process as an integral part of the place-conscious engineering activities they completed. The engineering design process is a sequence of steps engineers follow to identify and solve problems (Assumption Catholic School, 2022). It is iterative and can involve repeating steps as often as necessary to improve designs (Purdue University, 2020), fostering a culture where students gain insights and learn from their failures (Assumption Catholic School, 2022; May, 2020). The steps in the engineering design process include defining objectives and constraints, developing prototypes, and testing and evaluating solutions (Assumption Catholic School, 2022; May, 2020; Purdue University, 2020).

In the present study, students' place-conscious engineering activities involved identifying problems, setting constraints, and developing and iteratively improving air filters and flood prevention strategies consistent with the engineering design process. Qualitative data suggested that students iteratively improved their engineering designs and learned from failure. For example, BX5 said, “We had a lot of mistakes like the cardboard wasn’t on the ground or the cardboard wasn’t in the right place, the air filters weren’t in the right place, and then like the fan wasn’t in the right place, and we had to like retry and retry until we got it right, and it was really fun.” Beyond iteration and learning from failures, this statement also suggests that students improved their engineering designs to meet specific criteria. The statement also suggests that students experienced fun engaging in this process. Another student, BX6, said, “Yeah, we had to find the problem. And then so you had to test it, find the problem and then improve it.” Similar to BX5, this statement suggests that students encountered challenges and addressed them to improve their engineering designs, a process integral to the engineering design process. This study’s intervention and qualitative data provided evidence suggesting that students engaged with the engineering design process. Engagement in the engineering design process within place-conscious engineering may partly account for students' improved engineering career identities.

Prior research shows that engaging with engineering activities utilizing the engineering design process improves students' engineering identities (Capobianco et al., 2017; McLean et al., 2020). For example, McLean et al. (2020) found that participating in a collaborative engineering design activity encouraged elementary students to engage in and identify with engineering (McLean et al., 2020). In another study, Capobianco et al. (2017) found that engaging elementary students in authentic engineering design activities improved their engineering identities. The present study is similar to McLean et al. (2020) and Capobianco et al. (2017) in that these studies’ interventions included engaging students in engineering design and came up with similar findings. The congruence of the present study's findings with prior studies such as McLean et al. (2020) and Capobianco et al. (2017) could suggest a stronger link between engaging in the engineering design process and positive engineering career identity development. Overall, students' engagement with the engineering design process while completing place-conscious engineering activities could have contributed to their positive engineering career identities.

Research Question Two

This section discusses how the researcher addressed the second research question: What is the impact of engaging elementary students in place-conscious engineering activities on their attitudes towards engineering and technology? The section focuses on the quantitative results and specific aspects of the intervention that could explain the quantitative results.

This study found that students' participation in place-conscious engineering activities improved their attitudes towards engineering and technology. On a scale of 1 to 5, their mean S-STEM scores increased from 3.56 to 4.00, reflecting a percentage increase of 12%. This increase was statistically significant $t(19) = 3.12$, $p < 0.01$, indicating that changes in students' attitudes towards engineering and technology did not occur by chance but as a result of participating in place-conscious engineering activities (Dahiru, 2008). The corresponding Cohen's *d* value lay between 0.5 and 0.8, implying that the intervention had a medium effect size on the dependent variable (Mcleod, 2023; Sullivan & Feinn, 2012). Findings from this quantitative analysis suggest that students' participation in place-conscious engineering activities improved their attitudes towards engineering and technology. Other factors associated with these place-conscious engineering activities could have influenced these results.

Connecting Classroom Engineering to Students' Place.

One of the major aspects of the place-conscious engineering activities students completed was strongly connecting students' engineering learning to their local environments. This connection could have allowed students to see the link between classroom engineering content and prevailing local community issues. Qualitative data supported this claim. For example, BX20 said, "[engineers] solve problems in neighborhoods," suggesting that students thought engineers had a beneficial role in society - solving problems. Another student, BX4, said, "[engineers] find [people's] problem and then all, and then they find a solution to solve the problem by building something to help." This suggests that students understood that engineers can build things to help others. Students' thoughts of engineers as beneficial to society suggest that students connected classroom engineering to their local community contexts.

Students also acknowledged that during the year they participated in place-conscious engineering, they used classroom engineering to address local community issues. For example, when the interviewer asked, "So, is there anything that's different about engineering this year compared to engineering in the other years?" BX11 responded, "Well, this year we actually helped people um who suffered from the fire in Denton." Later, BX9 added, "We got to build air filters to help with the fire," suggesting that students used classroom engineering to help others. This statement further implies that students realized that engineering can help others and recognized their potential to use engineering to solve their local community problems. Qualitative data also suggested that students were happy to use engineering to help others. For example, BX11, said, “I think it [using engineering to help with the fire problem] made me feel like good about myself, since we’re helping people,” indicating that students valued helping people by providing engineering solutions.

The statements reviewed in this section suggest that students recognized the value of engineering in their communities and could draw connections between classroom engineering and its societal implications. Given that this realization occurred after participating in place-conscious engineering activities, the ability to see the connection between classroom engineering and societal impact may be a direct outcome of their involvement in these activities. Connecting classroom engineering to students’ local community issues could have contributed to students' improved attitudes towards engineering. This claim is consistent with existing literature suggesting that connecting classroom engineering learning to issues within students' communities can improve their attitudes towards engineering (Guzey et al., 2016).

Guzey et al. (2016) found that connecting classroom engineering learning to middle school students’ community issues, such as the declining loon population, improved their attitudes towards engineering. The present study is similar to Guzey et al. (2016) in that it tied students’ classroom engineering activities to their place and found that these activities positively influenced their attitudes towards engineering. With this congruence, the present study adds further evidence suggesting that connecting students’ engineering learning to their place effectively improves their attitudes towards engineering. This is important because research focusing on students’ attitudes towards engineering is still limited (Hammack et al., 2015; Lyons et al., 2009; Suprapto, 2016). The present study could contribute to building an overall understanding of how place impacts students' attitudes towards engineering.

Engineering Design Process.

In this study, when elementary students designed and built air filters for fire survivors, they actively participated in the learning process – iteratively brainstorming ideas for removing wildfire smoke from affected homes, developing designs, and assembling different parts to build the air filters. Similarly, when students designed flood prevention strategies, they engaged with the engineering design process by defining the problem, setting constraints, and iteratively modifying their designs to improve them based on their effectiveness and peer feedback. Qualitative data suggested that students' engagement with the engineering design process could have taught them that failure is part of engineering and an opportunity to improve engineering designs. For example, BX19 said, "[We learned that] sometimes you can make mistakes," suggesting that students understood that failure was normal in engineering. Learning from failure is essential in helping students cope with failures and maintain motivation for engineering engagement (Marks, 2017). Another indicator that students learned from failure emerged when they described their experiences building air filters. BX7 said, "We had many ideas, but we've tried them, and they didn't work. So, then we had ah, to think of another idea and then we thought of …" This statement shows that students learned from failure and experimented with different ideas to address the challenges they encountered while designing and building their air filters.

Students' statements also suggested that they understood that engineers engage in processes typical of the engineering design process. For example, when describing engineers' work, BX8 said, "I know that [engineers] design and like you said, and [engineers] improve, test…" Designing, testing, and improving are part of the engineering design process

(Assumption Catholic School, 2022; May, 2020; Purdue University, 2020). Findings from the present study suggest that students gained positive attitudes towards engineering and technology through engagement with the engineering design process. It is also worth noting that the engineering design activities students completed allowed them to learn engineering through actively participating in their learning. This could have also supported their attitudes towards engineering and technology. In fact, research associates active learning with students' improved attitudes towards subjects or disciplines (Tutal & Yazar, 2022).

The previous paragraphs suggest that students engaging with the engineering design process accounted for their improved attitudes towards engineering and technology. This observation agrees with prior studies (Cunningham & Lachapelle, 2010; Hammack et al., 2015; Mooney & Laubach, 2002). Cunningham and Lachapelle (2010) engaged elementary students in a program requiring students to engage with engineering design activities through creating, evaluating, and improving engineering designs. In Mooney and Laubach (2002), middle school students completed an engineering-based curriculum requiring them to complete multiple inquiry-based and open-ended activities as part of engineering design processes. In another study, Hammack et al. (2015) engaged middle school students in an engineering camp where students completed several engineering design activities. Findings from these studies suggested that students' participation in engineering design activities improved their attitudes towards engineering. The latter additionally showed that students' attitudes towards technology also improved. Therefore, engagement with the engineering design process as an integral part of place-conscious engineering could have contributed to students' improved attitudes towards engineering and technology.

Research Question Three

This section discusses how the researcher addressed the third research question: What do students' descriptions of their engagement with engineering activities reveal about their engineering identities and attitudes towards engineering and technology? The section presents the themes resulting from the focus group analysis.

Theme 1: Hands-On Engineering Activities.

This section discusses students' experiences with hands-on engineering activities and the possible effects of this involvement on their engineering identities and attitudes towards engineering.

First, qualitative findings showed that students experienced a heightened engagement in engineering during the year they participated in place-conscious engineering activities. They reported learning more engineering compared to previous years. For example, BX9 stated, "[We] did a lot more engineering things [this year]." Another student, BX21, said, "Oh, we learned a lot more about. Well, I learned a lot more about engineering." Then, BX22 responded, "Yeah, we all did. Like I think we all did." The statements by BX9 and BX21 suggest that students not only experienced a greater level of engagement with engineering during the year they participated in place-conscious engineering but also learned more about what engineering involves. Students' observations that they engaged in more engineering activities that year make sense. During that year, the curriculum provided greater opportunities for students to engage with engineering. Based on this observation, it is sensible that students claimed to have learned more about engineering during the year they completed place-conscious engineering. Literature suggests that hands-on engineering promotes students' engagement with engineering, as does place-conscious engineering (Westbrook, 2021). Students’ increased engagement with engineering could result from engaging with hands-on orientated, place-conscious engineering activities. Engagement in engineering-related coursework has the potential to foster the development of students’ engineering identities (Lappenbusch & Turns, 2007). It allows students to enhance their comprehension of engineering concepts (Westbrook, 2021), resulting in more positive engineering identities (Ju & Zhu, 2023). Therefore, participation in place-conscious engineering activities could have supported students’ development of their engineering identities through increased engagement in engineering.

Secondly, qualitative findings suggest that students had fun completing hands-on engineering activities and were excited to discuss them. This was evidenced by students’ active participation in discussing the completed hands-on engineering activities, eagerness to contribute to the discussion, and occasionally bringing back the discussion about hands-on engineering while discussing other issues. Students indicated that the hands-on engineering activities they completed were fun. BX6 said, “I like how [Emma, their teacher] does a lot of hands-on activities.” Then, BX5 responded, “Yeah,” and BX6 added, “It's really fun.” Another student, BX10, said the engineering activities they completed were fun because they involved “build[ing] new things,” which utilizes hands-on skills. The statements by BX6, BX5, and BX10 show that students experienced fun from engaging in hands-on engineering activities. Considering that these activities were situated within the broad context of place-conscious engineering could mean that the fun they experienced was also tied to place-consciousness. Situating hands-on engineering within students' place could have given these activities more relevance and value because they connected to students' community issues (Brooke, 2003; Winter, 2021). Students who see the value of learning engineering will likely develop positive engineering identities (Westbrook, 2021) and improved attitudes towards engineering (Brevik et al., 2014; Cunningham & Lachapelle, 2010; Mooney & Laubach, 2002). Likely, engaging with hands-on engineering within the broad context of place-conscious engineering could have contributed to students' engineering identity development and attitudes towards engineering.

Theme 2: Societal Utility of Engineering.

This section discusses how students connected engineering to society, their perceptions of the purpose of engineering in society, and their experiences participating in engineering within their local communities.

Findings from this study suggest that engaging in place-conscious engineering activities helped bridge the gap between school engineering and students' communities. During the year they participated in place-conscious engineering activities, students connected classroom engineering to society. Specifically, students learned that engineering was a valuable tool for addressing problems within their communities and society. They claimed that their understanding of the role of engineering changed following their participation in that year's engineering activities. For example, the interviewer asked, "So, based on what you did this year, does it change your understanding of what engineers do?" BX13 responded, "Yeah," and BX12 added, "Yes". These statements suggest that students noticed a difference in the engineering they learned during that particular year compared to previous years, with a major distinction being its impact on their perceptions of engineers' work. When the interviewer asked, "How [is] your understanding of engineering different now?" BX12 responded, "I used to think all engineers just built, built things. Now I know they build things to help people" and BX14 added, "Yeah." BX12 and BX14's responses suggest that students developed a better understanding of engineers' work, by linking it to its purpose. Another student, BX22, stated, "I think we learned more of what engineer[ing] actually was." The second statement by BX12 suggests that the student only associated engineering with "building" until they participated in this study and realized that engineers build things to help people. Students' shift in understanding of engineers' work could result from participating in place-conscious engineering activities. This is because the shift only happened after participating in place-conscious engineering. It is logical to attribute the shift in students' perceptions of engineers' work to their involvement in place-conscious engineering activities, considering that these activities focused on linking classroom engineering to local problems and developing engineering solutions to address them.

Some students explicitly situated the usefulness of engineering within the context of problem-solving in their local communities. For example, BX20 stated, "[engineers] solve problems in neighborhoods," suggesting that students acknowledged the usefulness of engineering within their communities, particularly by addressing local problems. BX4 said, "Oh they, they find your [people's] problem and then all and then they find a solution to solve the problem by building something to help." Beyond what BX20 said, this statement adds that engineers also identify and address problems through building. This perception could result from students' experiences with place-conscious engineering activities such as building air filters. When students built air filters, they first identified the wildfire smoke problem and then designed engineering solutions by building air filters to address it, which is consistent with BX 4's statement. Other examples of a student's statement highlighting the usefulness of engineering in society came from BX22, who stated, “So like they [engineers] help people in like, let's say, if there's a problem like what we did, we help solve a problem like with our air filters,” indicating that engineers solve problems for people. Similar to the previous statements by BX20 and BX4, this statement was influenced by students’ prior experiences building air filters. In explaining what engineers do, BX22 said they solve problems and gave an example of how this explanation was consistent with their prior experiences, specifically why they built air filters. When students described what they would do if they became engineers, BX20 stated, “If the people have problems, we could at least try to solve for people to make it make them happier,” suggesting that engineers solve problems and help people. These statements suggest that students strongly linked engineering to addressing people’s problems, and BX20 explicitly stated that the goal of helping people is to make them happier. This suggests that students realized engineering could do more than just help people; it can also contribute to their happiness. Notably, in describing engineering work, BX20 and BX22 seemed to position themselves as engineers – they used the word “we” to describe engineers, suggesting that they viewed themselves as engineers. Their perception of themselves as engineers could directly stem from their previous experiences engaging with place-conscious engineering activities, which enabled them to tackle real-world challenges like professional engineers. Literature suggests that envisioning oneself as an engineer can foster positive engineering identities (Rodriguez et al., 2018). The finding that students linked engineering with societal issues reemerged when they talked about what they would do if they became engineers. Students aspired to develop projects that solve societal problems related to ground transportation, space exploration, food security, prosthetics, and natural disasters. This further supports the claim that students viewed engineering as a tool for addressing societal challenges, a perception likely resulting from their prior engagement in engineering that addressed societal challenges. The quotes discussed in this section strongly suggest that students connected engineering to society during the year they participated in place-conscious engineering activities.

Students' change in their understanding of what engineers do (i.e., perceiving engineers as helpful to society) could result from participating in place-conscious engineering activities. This could be true because place-conscious learning emphasizes establishing a connection between school learning and students' local issues (Elfer, 2011; Gruenewald, 2003), consistent with the engineering activities students completed (i.e., building air filters for wildfire survivors affected by wildfire smoke and designing flood prevention strategies for a local river that often floods due to ice jams). The place-conscious nature of these engineering activities could partly explain why students connected engineering to society. This claim is consistent with literature suggesting that place-conscious curricula bridge local engineering issues and formal school engineering knowledge (Avery, 2013; Buxton, 2010; Johnson et al., 2009; Lee et al., 2012). Additionally, Brooke (2003) indicates that students tend to perceive learning linked to their local contexts as beneficial. Students who value their engineering education are more likely to develop positive engineering identities (Westbrook, 2021). This means that participation in place-conscious engineering activities could have positively influenced students' engineering identities by enabling them to connect classroom engineering concepts with societal applications and recognize their societal value.

Theme 3: Learning from Failure and Engagement in Collaboration.

This section discusses students' experiences with authentic engineering through (1) learning from failure and (2) completing engineering tasks through collaborative efforts.

Learning from Failure. Learning from failure encompassed students solving problems by iteratively modifying their designs and products to meet desired requirements. The place-conscious engineering activities they completed allowed them to learn from failure. Students independently devised solutions after identifying the problems (such as smoke pollution from a wildfire and flooding due to ice jams) and defining engineering objectives and constraints. This independence allowed them to explore various solutions and learn from unsuccessful attempts. Qualitative data corroborated this observation. For example, when students described their experiences working with place-conscious engineering, they reported encountering several problems and devising methods to rectify them, typical of learning from failure. BX5 said, “We had a lot of mistakes like the cardboard wasn't on the ground or the cardboard wasn't in the right place, the air filters weren't in the right place, and then like the fan wasn't in the right place, and we had to like retry and retry until we got it right, and it was really fun.” This statement indicates that students faced multiple challenges while designing and building air filters, necessitating an iterative process of trying and testing various solutions until they overcame the challenges. Iteratively trying and testing different solutions allowed students to learn from failure and improve their engineering designs.

To add to the discussion about their experiences completing place-conscious engineering activities, BX7 said, “We had many ideas, but we've tried them, and they didn't work. So, then we had ah, to think of another idea" and BX6 commented, "Yeah, we had to find the problem, and then so you had to test it, find the problem and then improve it." Statements from BX5, BX6, and BX7 suggest that students encountered problems while building air filters and devised solutions to address them. These statements also suggest that students were persistent in addressing the problems they encountered. Similarly, BX16 said, "I like building the air filters coz most of the time, if you messed up, you'd have to rebuild everything," suggesting that the students effectively handled their emotions following unsuccessful attempts to solve the problems they encountered. Maintaining a positive attitude after failure could suggest that students enjoyed learning from failure. Consistent with this claim, BX5 described making mistakes and devising solutions as "really fun." Another student, BX19 stated, "[We learned that] sometimes you can make mistakes…" This implies that students not only learned from failure and iteratively modified their engineering designs, but they also coped with the emotional challenges associated with failed engineering designs. This could be why they reported experiencing fun in learning from failure. In addition, based on BX5's statement, it appears that students understood that encountering failure in engineering is a normal aspect of engineering. In addition to learning from failure, a closer analysis of the intervention showed that students' place-conscious engineering activities also encompass defining problems and developing, testing, and improving engineering designs. These steps are crucial components of the engineering design process (Mangold & Robinson, 2013).

Findings suggested that students' engagement with learning from failure and the engineering design process could have supported their engineering identities and attitudes towards engineering. This is consistent with literature suggesting that engagement with the engineering design process can positively influence students' engineering identities (Cunningham & Lachapelle, 2010; Hammack et al., 2015; Mooney & Laubach, 2002). Regarding attitude, findings suggested that students reported experiencing fun from engaging with the engineering design process, which could suggest positive attitudes toward the engineering design process. Since the engineering design process is integral to engineering, this could suggest a corresponding positive attitude towards engineering. The present study is unique because it purposively situated engineering design within students' local community issues and suggested that students' engineering identities and attitudes toward engineering improved. Since students completed engineering design activities within place-conscious engineering, the effects of engineering design activities could also depend on the place-conscious context of these activities.

<u>Collaboration</u>. Collaboration encompassed students working together to complete engineering tasks. Firstly, the place-conscious engineering activities students completed allowed them to work in small groups of three to four students per group. When students discussed the place-conscious engineering activities they completed, they indicated that they completed some activities as groups. In describing how they developed flood prevention strategies they completed, BX7 said, "Me and BX13 were a team", indicating that students completed some engineering tasks collaboratively. Further evidence suggesting that students collaborated came from BX7, who said, "Whenever we had the tiny levees we made ah, we went around and gave notes [feedback] to the teams, other teams…" This statement shows that students completed their engineering activities with the help of their peers. It further suggests that students utilized their peers' opinions and feedback to enhance their engineering designs. This peer support assisted them in completing their engineering projects according to set criteria or expectations. Evidence

supporting this claim came from BX5's response, "…and kind of helped make the plans better... We also didn't have to argue as a group… so everybody got to put in their opinion." In this statement, BX5 explicitly said working in groups and providing peer feedback helped improve their engineering plans. Based on this, it is sensible to think collaboration enhanced their success in completing their place-conscious engineering tasks. The last part of BX5's statement, "We also didn't have to argue as a group… so everybody got to put in their opinion", indicates that students understood the role collaboration and their peers' opinions played toward achieving their engineering goals.

Students justified why they thought collaboration and peer feedback were essential. For example, BX7 said, "Because like yeah, I know some people have some good ideas, but like, if you don't listen to other people's ideas, then you won't know if their idea is better than yours, or not like better than yours, or like, that will work better." This statement strongly suggests that students recognized the importance of peer feedback, understanding that without it, they might be confined to their own ideas and overlook alternative approaches that could assist them in improving their engineering designs. Further evidence suggesting that students valued collaboration in completing engineering tasks resurfaced when students described what they would do if they became engineers. For example, BX20 said, "I might also like, gather some of my friends that wanted to be an engineer and like, make a miniature company." This statement implies that students believed that collaboration was crucial not only for completing classroom engineering activities but also for real-world engineering projects. The statements reviewed in this section suggest that students completed engineering activities collaboratively and understood their importance in completing engineering projects.

Collaboration is one of the attributes of authentic engineering (Bosman & Fernhaber, 2018). Students' engagement in authentic engineering can positively influence their engineering identities (Ju & Zhu, 2023; Schell et al., 2018) and attitudes toward engineering (Springer et al., 1999). In discussing possible connections between students' collaboration and their attitudes towards engineering, it is crucial to remember that SCCT indicates that positive attitudes towards engineering can influence individuals' career choices (Lent et al., 1994). Hammack et al. (2015) specifically state that positive attitudes towards engineering can encourage students to pursue engineering degree programs. Therefore, collaboratively completing place-conscious engineering activities could have positively influenced their career aspirations through improved attitudes towards engineering.

Theme 4: Satisfaction from Learning Engineering.

This section discusses students' level of satisfaction with the place-conscious engineering activities they completed during the year they participated in place-conscious engineering activities. Indicators of satisfaction or dissatisfaction included an evaluation of whether students (1) had complaints about the engineering activities they completed, (2) expressed a desire to continue learning engineering similar to how they learned it during that particular year, (3) and wished for the upcoming fourth graders to experience engineering learning similar to their own.

Findings from the present study suggest that students expressed satisfaction with the place-conscious engineering activities they completed. The first indicator of satisfaction was that most students stated that there were no additional activities they wished they had completed during the year they participated in place-conscious engineering activities. This observation suggests that students were satisfied with the activities they had completed during that particular year. For example, when the interviewer asked, “Is there any engineering project you wish that you would get to do that you haven’t done yet?” BX9 responded with “No,” BX11, “Not really,” and BX10, “I don’t really know any projects.” These responses suggest that students were satisfied with the engineering activities they had completed during the year they participated in place-conscious engineering activities. The place-conscious nature of these activities probably contributed to this satisfaction.

The second satisfaction indicator was that students expressed interest in continuing to learn engineering. For example, BX14 stated, “I’m excited for next year because I think we’re gonna do more [engineering],” suggesting that students’ excitement resulted from their anticipated engagement with engineering. In other words, students wanted to continue learning engineering and were excited about it. When the interviewer asked, “So, you guys go to middle school next year… Do you hope you have engineering there?” BX9, BX10, and BX11 all responded affirmatively, “Yeah,” further suggesting that they desired to continue engaging with engineering. In a different instance, the interviewer asked, “Do you hope you do engineering next year in the middle school?”. Then, BX13 and BX14 responded affirmatively, “Yes”. The interviewer asked, “Yeah? Do it like the way Emma does it?”. Then, BX13 and BX14 responded, “Yeah”. The conversation between the interviewer and BX13 and BX14 suggests that students wanted to continue learning engineering as they did with their teacher, Emma, who taught it. Emma engaged students in place-conscious engineering activities, suggesting that students wanted to engage more in place-conscious engineering. One would argue that if students were not satisfied with their experiences learning engineering in a place-conscious manner, they would not have anticipated further engineering learning. In this case, students’ willingness to continue engaging with engineering suggests satisfaction with learning engineering in a place-conscious manner.

The third satisfaction indicator is that students advocated for Emma to continue teaching engineering to the next fourth graders. When the interviewer asked students if Emma should continue teaching engineering in the manner she did, students responded affirmatively. For example, the interviewer asked, “When she (Emma) has new kids (students) next year. Do you think she should keep doing engineering?” BX15, BX16, and BX17 responded affirmatively, and BX18 added, “Yes because it's a really fun activity to do and it teaches them [fourth graders] that engineering is actually really good.” It is sensible to think that if students were not satisfied with the engineering they learned during that year, they would not have recommended that the upcoming fourth graders similarly learn engineering. Students' statements suggest that students were satisfied with learning engineering during that particular year. Furthermore, considering that the engineering curriculum of that particular year emphasized place consciousness, students’ statements suggest that they enjoyed engaging in place-conscious engineering activities.

It is crucial to remember that students' engineering learning connected to their local community issues. Students tend to regard curricular connecting classroom learning to students’ communities as valuable (Brooke, 2003), and students who value their engineering learning experiences tend to develop positive engineering identities (Westbrook, 2021). The findings of this study suggest that students valued learning engineering, which could imply that this experience helped them cultivate positive engineering identities. Also, students' desires to continue learning engineering could indicate positive engineering identities. Prior literature supports this assertion, stating that engineering identities are closely associated with the desire to learn engineering (Pierrakos et al., 2009). Desire to continue learning engineering could mean that students envisioned themselves as engineers. Envisioning oneself as an engineer can foster positive engineering identities (Rodriguez et al., 2018) and persistence in learning engineering (Godwin et al., 2013; Tonso, 2007; Verdín et al., 2018). In summary, this paragraph provides evidence suggesting that the place-conscious engineering activities students completed positively influenced their engineering identities through their satisfaction with these activities. Students' satisfaction with the place-conscious engineering activities they completed could have contributed to growth in their engineering identities.

One of the indicators of students' satisfaction with learning engineering was their desire to continue learning engineering. Students' inclination to continue engaging with engineering could indicate positive attitudes toward engineering. This is because individuals tend to have inclinations towards actions they have positive attitudes towards (Ajzen, 2001). Inclinations to engage and persist in performing certain activities (i.e., learning engineering) can indicate positive attitudes towards those activities (Besterfield-Sacre et al., 1998; Olufemi, 2012). Students' desires to continue learning engineering could partly account for the growth in their attitudes towards engineering. Overall, findings from the present study suggest that students were satisfied with learning engineering in a place-conscious fashion, which could have contributed to their positive engineering identities and attitudes toward engineering.

Theme 5: Positive Perceptions of Engineers as Highly Skilled.

This section discusses how students perceive engineers' capabilities and usefulness to society. It specifically focuses on students' views of engineers' capabilities to complete complex engineering tasks and the impact of completing such tasks on the well-being of society.

Findings showed that students perceived engineers as highly skilled individuals capable of completing a wide range of engineering tasks that serve some of society's pressing problems. For example, when they discussed what engineers do, students associated engineering with a wide range of tasks such as "building," "fixing," "designing," "testing," and "improving." This means that students believed that engineers were capable of completing such tasks. When students discussed engineers' work, BX6 stated, "Engineers do more than just like little things like they build cars; they find out like big problems; they do a lot of things." BX6's statement suggested that engineers could tackle complex problems. The use of the phrase "They find out like big problems" substantiates this claim as BX6 associates engineering with tackling "big problems." Similarly, the last part of BX6's statement, "They do a lot of things" suggests that students not only considered engineers as capable of addressing complex problems but also a wide variety of problems.

BX7 made a statement with similar meaning, "They [engineers] can do anything from making a car fly to making a bike that flies," and then BX6 responded, "Yeah, they can do anything." BX7 gave specific examples of engineering tasks engineers could complete, such as building flying cars and bikes. At the time of the interview, these products were not mainstream modes of transportation, but students believed that engineers could build such products. The statement from BX7 strengthens the claim that students considered engineers to be highly skilled individuals capable of completing complex engineering tasks. BX6’s statement further suggests that engineers can complete a wide range of engineering tasks.

Other students’ statements suggested that they perceived engineers as holding solutions to some of society’s problems. For example, BX7 mentioned that “they [engineers] do big stuff, and they help out the world,” and BX20 commented that “[engineers] solve problems in neighborhoods.” While the first part of BX7’s statement agrees with previous claims that students viewed engineers as capable of executing complex engineering tasks, the latter indicates that students also regarded the work of engineers as beneficial to the world. This suggests that students recognized engineering not just as an end in itself but also as a means to an end - they appreciated that engineers are not only capable of addressing complex problems in their entirety but also valued their engineering skills as beneficial to society. As evidenced by students using the word “neighborhoods,” BX20’s response to BX7 provides a unique perspective on engineers' capabilities to address complex problems, specifically by connecting it to students' local contexts – recognizing that engineering benefited students' local environments. In addition to these statements, students implicitly suggested that engineers addressed societal problems when they discussed projects they would engage in if they became engineers. These projects included building cars for transportation, improved space suits, and prosthetics for people and animals with missing limbs. This further supports the claim that students perceived engineering as beneficial to society.

As discussed in Theme 1 of Chapter 5, students hardly engaged in engineering and had limited understanding of what engineering involved before participating in place-conscious engineering activities. Students' participation in place-conscious engineering activities could partly account for their positive perceptions of engineers as highly skilled and beneficial to society. The two place-conscious engineering activities students completed (building air filters for fire survivors and flood prevention strategies for a local river) allowed students to address real-world challenges just as real-world engineers would, which could have influenced their perceptions of engineers and their work. It could also stem from their interactions with a real-world floodplain engineer who demonstrated how he addresses flood challenges on rivers within the state. Students' positive perceptions of engineers could have influenced their engineering identities and attitudes towards engineering, as illustrated below.

Individuals' perceptions are related to and influence their attitudes (Pickens, 2005). Students' positive perceptions of engineers could have positively influenced their attitudes towards engineering. Another factor that could have positively influenced students' attitudes towards engineering is their perceptions of engineering as beneficial to society. Positively perceiving an action's outcome is associated with positive attitudes toward such actions (Ajzen, 2001). This provides further evidence suggesting that students could have developed positive attitudes toward engineering.

As discussed in prior paragraphs of this section, students appeared to have positive perceptions of engineering and viewed engineering as a valuable tool for addressing some of society's problems. Students who perceive engineering as beneficial will likely develop positive engineering identities (Westbrook, 2021). Based on this, students may have developed positive engineering identities and perceptions of engineering. Since participation in place-conscious engineering activities could have helped students develop positive perceptions, they might also have helped students develop positive engineering identities.

Theme 6: Engineering Career Aspirations.

This section discusses students' engineering career aspirations after participating in place-conscious engineering activities. The discussion starts by describing students' responses to a question asking them to state if they considered becoming engineers in the future.

The researcher evaluated students' engineering career aspirations by comparing their positive, neutral, and negative responses to the question asking them to state if they considered pursuing engineering careers. When students discussed the place-conscious engineering activities they completed, the interviewer asked students, "Do you think you would be interested in being engineers when you grew up? The researcher classified students' responses as positive (indicating that the students intended to pursue engineering), neutral (indicating that the students were unsure about pursuing engineering), and negative (indicating that the students had no intentions of pursuing engineering). Students who provided positive responses used words such as "yep," "yes," and "yeah." Those who provided neutral responses vacillated between different career options, including engineering (i.e., BX8 said, "Maybe an accountant, maybe an engineer. I don't really know.") or used words such as "maybe." Finally, those who gave negative responses used words such as "no" or responded with a non-engineering career, such as "a professional baseball player."

The positive category registered the highest number of students, followed by the neutral and negative categories. When compared across these categories, the greatest proportion of students' responses fell into the positive category, indicating that the greatest proportion of students aspired to pursue engineering careers. Students who provided positive responses may have had positive engineering identities. Literature indicates that students with robust engineering identities tend to perceive themselves as aspiring engineers (Godwin et al., 2013; Matusovich et al., 2010; Rodriguez et al., 2018). This perception can foster an inclination towards pursuing engineering degrees (Matusovich et al., 2010). Therefore, students who responded positively may have positive engineering identities. Students' desire to pursue future engineering careers could result from participation in place-conscious engineering activities. These activities allowed students to engage in real-world engineering, just as professional engineers would – address real-life problems. This could have allowed students to experience what real-world engineering involves, especially its association with helping others. Then, it could have encouraged them to envision themselves as engineers because they became aware that engineering could be a tool for helping others, which they valued. In addition, it is also worth noting that students interacted with a floodplain engineer, which may have also impacted their engineering career aspirations.

Since the greatest proportion of students' responses fell into the positive category, one would argue that the greatest proportion of students considered pursuing engineering careers. Inclinations to engage and persist in performing certain activities (i.e., learning engineering) can indicate positive attitudes towards those activities (Besterfield-Sacre et al., 1998; Olufemi, 2012). A positive relationship exists between students' interest in pursuing engineering careers and their attitudes towards engineering (Hirsch et al., 2007; Wiebe et al., 2018). Overall, students' interest in engineering careers could indicate favorable attitudes towards engineering.

An examination of students who provided negative responses indicated that their career aspirations aligned with the careers of the individuals they were close to. One of these students, BX6, drew inspiration from the mother and expressed the desire to become a lawyer, stating, "[I want to be] a lawyer, follow[ing] in my mum's footsteps." Another student, BX9, aspired to become a professional baseball player, following in the footsteps of his parents' friend, stating, "I [am] really into baseball, so one of my brother's friends is a multimillionaire, and he played baseball." Inspired by their engineering teacher, another student, BX7, expressed interest in becoming an engineering teacher, stating, "Ah well, I want to be a teacher though. But I want to be like an engineering teacher like I wanna. I basically wanna be a mini [Emma] (their teacher)." Based on students' quotes, one would conclude that students' career decisions can be functions of careers held by the people they interact with. Existing literature also supports this assertion (Nauta & Kokaly, 2001; Perrone et al., 2002; Quimby & De Santis, 2006). This observation may have implications for increasing students' participation in engineering-related careers. Among other strategies, encouraging students to pursue careers in engineering may be facilitated by providing them with exposure to professionals currently working in engineering-related fields.

Research Question Four – Mixing Quantitative and Qualitative Data

This section discusses how the researcher addressed the fourth research question: How do the findings from the qualitative interview support the findings from the quantitative survey? This section has two main subsections: one addressing the engineering identity construct and the other the attitudes towards engineering and technology construct.

Engineering Identity

This section discusses students' engineering identities. The section is divided into two subsections: (1) academic subscale and (2) engineering career subscale.

Academic Subscale. In the present study, academic identity referred to students' "self-beliefs in who they are as students" (Capobianco et al., 2012, p. 703). Quantitative results suggested that the EIDS did not detect a significant increase in students' academic identities. The researcher considered these quantitative results inconclusive because further analysis revealed that the EIDS measured students' academic identities with poor internal consistency. In fact, Capobianco et al. (2012) also found that the EIDS's academic subscale measured students' internal consistency poorly and stated, "Item performance will not differ systematically for students with low and high total scores" (p. 709). The low internal consistency of the EIDS in the present study is problematic, as internal consistency is related to and can affect the validity of the results (Tavakol & Dennick, 2011). Therefore, drawing unbiased conclusions about students' academic identities from quantitative data was challenging.

However, qualitative data suggested that students' academic identities improved after participating in place-conscious engineering activities. For example, qualitative data related to the first item of the academic subscale (I do my school work as well as my classmates) indicated that students wanted to continue learning engineering in the following grades. BX14 stated, "I'm excited for next year because I think we're gonna do more [engineering]." This statement suggests that students wanted to continue engaging with their school work – they anticipated more engagement in their school work in future grades. It follows that the desire to continue engaging with school work indicates positive academic identities (Capobianco et al., 2012).

Further, qualitative data related to the fourth item of the academic subscale (I am good at working with others in small groups) also provided evidence that students developed positive academic identities. For example, students mentioned that they worked collaboratively and seemed to have understood the value of collaboration in completing engineering tasks. For example, BX5 said, "[collaboration] kind of helped make the plans better, and like other people's opinions that way. We also didn't have to argue as a group with like one opinion." This suggests that students worked well in small groups. This makes sense, considering that students seemed to value their peer's opinions by not arguing. Overall, although the EIDS did not detect a significant increase in students' academic identities, qualitative data provided evidence that students' academic identities improved because of participating in place-conscious engineering activities.

Engineering Career Subscale. In the present study, engineering career identity referred to students' "self-goals, aims, or objectives of becoming an engineer" (Capobianco et al., 2012, p. 703). According to Capobianco et al. (2012) some indicators of positive engineering career identities include students' (1) awareness that engineers solve problems to help people, (2) understanding that engineers work in teams, (3) perception of engineers as responsible for building things around them, and (4) awareness of the existence of different kinds of engineers indicate positive academic identities (5) awareness that engineers use mathematics, (6) awareness that engineers use science, (7) perceptions of engineers as creative, (8) desires to pursue engineering careers, (9) desires to solve engineering problems that help people, (10) desire to work in teams. In the present study, the quantitative piece of the study used these constructs to measure students' engineering career identities. Qualitative data supported these constructs and reinforced the quantitative findings that students developed positive engineering career identities after participating in place-conscious engineering activities. The specific ways in which qualitative data supports quantitative data are discussed.

Firstly, students mentioned that engineers solved problems that helped people. For example, BX20 said, "[engineers] solve problems in neighborhoods." Similarly, BX11 said, "Engineers help people." These statements suggest that students perceive engineering as a tool for helping people. Secondly, students indicated that engineers worked in teams. BX20 said, "[If I were an engineer] I might also like, gather some of my friends who wanted to be an engineer and like, make a miniature company." BX20's statement suggests that the students believed engineers work collaboratively—they positioned themselves as engineers and expressed a desire to establish an engineering company to execute engineering activities collaboratively. Thirdly, students' statements also suggested that they viewed engineers as responsible for designing everything around them. For example, BX9 mentioned, "[Engineers] design cars and build them," and BX6 said, "Yeah, they can do anything," suggesting that engineers are capable of designing and building virtually anything around them. Qualitative data also showed that students acknowledged that there are different kinds of engineers. For example, BX5 said, "And there are a lot of types of engineers." This statement clearly shows that students were aware of more than one type of engineer.

In addition, students indicated that engineers used mathematics and science. When the interviewer asked, "Do you think engineers use math in what they do?" BX23 responded, "Yeah," and BX2 said, "Oh yeah!" indicating that students believed engineers used mathematics. BX7 commented, "[Engineers] figure out like how much pressure can go into a car tire to make sure it doesn't pop on the road when it hits a little pebble." This statement from BX7 suggests that engineers use scientific concepts, such as pressure, in their work. BX23 and BX7's statements suggest that they believed that engineers use mathematics and science in their work. Aside from that, qualitative data also suggested that students perceived engineers as creative. For instance, BX7 stated, "[Engineers] can do anything from making a car fly to making a bike that flies. One would argue that these modes of transportation, being unconventional and not part of mainstream transport technology, represent creativity in engineering." Based on this analysis, it is sensible to conclude that students believed that engineering involves creativity.

Additionally, some students were interested in becoming engineers when they grew up. When asked, "Do you think you'd be interested in being an engineer when you grow up?" BX6 replied, "Yeah," indicating a desire to pursue an engineering career. Another important observation was that students wanted to solve problems that help people. For example, BX22 said, "[If I were an engineer] I would probably get together with some other engineers and see if the people have problems, we could at least try to solve them to make them happier." This shows that students had aspirations to address people's problems through engineering. Finally, students indicated a wish to work as a team with other engineers in the future. For example, BX20 stated, "[If I were an engineer] I might also, like, gather some of my friends who wanted to be engineers and, like, make a miniature company." The statement shows that students aspired to work collaboratively with other engineers in the future.

Overall, qualitative data supported quantitative data. The two data types suggested that students' engineering career identities improved after participating in place-conscious engineering activities. This means that participation in place-conscious engineering activities improved students' engineering career identities.

Attitudes Towards Engineering and Technology

Quantitative findings and corresponding qualitative findings suggested that students' attitudes towards engineering and technology improved after participating in place-conscious engineering activities. According to Friday Institute for Educational Innovation (2012), several indicators reflect students' positive attitudes toward engineering and technology. These indicators include (1) envisioning the creation of new products, (2) the belief in their ability to enhance everyday items through engineering, (3) seeing themselves as proficient in building and repairing things, (4) demonstrating an interest in understanding the workings of machines, (5) the conviction that designing products or structures is critical for their future careers, (6) curiosity about the functionality of electronics, (7) aspiring to integrate creativity into their future work, (8) the belief that mathematics and science skills are crucial to innovating new items, and (9) confidence in their potential success in an engineering profession.

Firstly, students indicated that they envisioned themselves creating new products. For example, following the interviewer's question, "So you said it (engineering) was fun. What makes it fun?" BX10 responded, "Getting to build new things," suggesting that students envisioned themselves building new products. Similarly, when students discussed what they would do if they became engineers, they discussed designing and building products such as prosthetics. BX14 said, "would probably build stuff to help people… Um, like, like, prosthetic legs and stuff". Statements from BX10 and BX14 suggest that students imagined themselves creating new products by applying their engineering skills. Secondly, students believed in their ability to enhance everyday items through engineering. This is evidenced by BX23, who said, "If I became an engineer, I'd probably make like inventions that would help, like, people." Similarly, another student, BX15, said, "I would build an iPhone 200, [with an] amazing camera quality. Students imagined themselves using engineering to create and improve everyday products. Thirdly, students seemed convinced that designing products or structures is critical for their future careers. For example, the interviewer asked, "So imagine it is 20 years in the future, and you have gone to school and become an engineer. What do you think you would do?" Then, BX9 responded, "Design[ing] cars and build[ing] them." and BX11 added, "Ah, I would do the same thing." These statements suggest that they imagined themselves designing and building products in the future and regarded them as essential. Additionally, students showed curiosity about the functionality of electronics. BX14 said, "Hopefully, we can build more things and not really like, like, more of the fan things. Because we do other, other things, but it's not as like high-tech as the fan. Like, like doing the dinosaur thing? We're not actually building something that moves and stuff." Then the Interviewer asked, "So you want to make things that have motors or electronics or something like that?" BX14"Yeah." This suggests that students possessed curiosity for learning how electronic devices worked and wanted to build them.

Furthermore, students aspired to integrate creativity into their future works. BX23 said, "If became an engineer, I'd probably make like inventions that would help like, people." Based on this statement, it can be argued that students were inclined to utilize creativity in their future endeavors, recognizing that invention inherently demands a degree of creative thinking. Also, Students believed that mathematics and science skills were crucial to innovating new products. When the interviewer asked, "So you do use math during engineering?" BX23 responded, “Yeah,” and BX2 added, “Oh yeah.” These responses suggest that students believed mathematics was a crucial engineering component. Another student, BX7, said, “[Engineers] figure out like how much pressure can go into a car tire to make sure it doesn’t pop on the road when it hits a little pebble,” suggesting that students believed that engineers use scientific concepts such as the (i.e., the concept of pressure) to develop designs (i.e., tires). Finally, Qualitative data also suggested that students had confidence in their potential to succeed in engineering. The interviewer asked, “So, have you ever thought about being an engineer? Is that something you would be interested in?” “BX1 responded with “Yes,” BX23 with “Definitely,” and BX4 with “Kind of’.” The affirmative response from these students suggests that students had desires to pursue engineering careers. One would argue that if students had no confidence in their abilities to pursue engineering careers, they would not consider pursuing them. Therefore, it is reasonable to conclude that students expressed confidence in their abilities to pursue engineering careers.

In conclusion, this section explored how qualitative findings supported the quantitative results. The analysis offers clear evidence of qualitative findings and supported the quantitative findings. Taken together, both quantitative and qualitative findings indicate that students' engagement in place-conscious engineering activities improved their attitudes towards engineering and technology.

Implications

The NGSS requires elementary teachers to incorporate engineering into their science curricula (NGSS Lead States, 2013). While doing this, they must employ teaching strategies that positively influence students’ engineering identities and attitudes towards engineering.

Improving students' engineering identities and attitudes toward engineering is crucial for promoting students' persistence in learning engineering (Besterfield-Sacre et al., 1998; Patrick & Prybutok, 2018). Students' engineering identities and attitudes towards engineering predict whether they pursue engineering careers (Hirsch et al., 2007; Pierrakos et al., 2009). This study found that students' participation in place-conscious engineering activities significantly improved their engineering identities and attitudes towards engineering and technology. The following paragraphs discuss the implications of this study's findings for (1) engineering education and (2) professional development.

Implications for Engineering Education

Elementary teachers wanting to improve students' engineering identities and attitudes towards engineering and technology should consider introducing them to place-conscious engineering activities. They should consider integrating local contexts, challenges, and projects into the engineering curriculum. In the present study, elementary students participated in two major place-conscious engineering activities: building air filters for fire survivors and designing flood prevention strategies for a nearby river. These place-conscious engineering activities allowed students to connect engineering to their local community issues and see the value of engineering in society. Results suggest that students developed positive engineering identities and attitudes towards engineering and technology due to participation in place-conscious engineering activities. Students' engineering identities and attitudes towards engineering and technology are crucial because they determine whether students pursue engineering careers (Depieri & de Deus Lopes, 2014; Godwin et al., 2013). The present study suggests that the place-conscious engineering activities students completed allowed them to see the usefulness of engineering in society and associate engineering with solving various societal problems. According to SCCT, outcome expectations (i.e., individuals' beliefs about the results of engaging in a particular behavior) influence people's career interests, decisions, and behaviors (Ali et al., 2005; Gore Jr & Leuwerke, 2000; Wöhrmann et al., 2013). Individuals tend to choose career paths likely to produce positive results (Gore Jr & Leuwerke, 2000). Therefore, students' engagement in place-conscious engineering activities may improve their engineering identities, attitudes toward engineering and technology, and the possibility of pursuing engineering careers. Teachers wanting to leverage these benefits of place-conscious engineering should consider implementing these interventions while students are in early elementary grades. Developing students' engineering identities and attitudes towards engineering and technology early in elementary school is crucial. Students tend to make career choices during middle school (Matusovich et al., 2021; Wyss et al., 2012). Early interventions could encourage students to pursue engineering careers.

To promote the effective use of place-conscious engineering curricula, teachers must be competent in implementing such curricula. While an in-service teacher implemented this study's place-conscious engineering activities, the researcher recognizes that in-service teachers start their teaching journey in teacher preparation programs. Teacher preparation programs influence elementary pre-service teachers' teaching methodologies in their classrooms. Teacher preparation programs should consider incorporating strategies for effectively implementing place-conscious engineering curricula within their science methods courses. This could help prepare elementary pre-service teachers to consider implementing place-conscious engineering activities in their classrooms and equip them with the necessary competencies to implement such curricula.

Including this content in science methods courses could raise awareness among elementary pre-service teachers about the advantages of employing place-conscious teaching methods, motivating them to integrate these approaches into their classrooms.

Implications for Professional Development

In the present study, the teacher (Emma) who implemented place-conscious engineering activities first participated in a professional development (PD) program. Emma completed the PD as a member of a professional learning community (PLC) consisting of teachers, instructors from a partner community college, and engineering and science education professors from a local university. The PD allowed the teacher to brainstorm place-conscious engineering activities, develop corresponding curricula, and effectively implement the curricula. Based on this example, suppose schools and school districts are to help their elementary students develop positive engineering identities and attitudes towards engineering and technology. In that case, they should consider building their elementary teachers' competencies to implement place-conscious engineering activities effectively. To ensure the success of such PD programs, school leaders should consider establishing professional learning communities that bring together teachers, community members, and engineering experts (i.e., engineering and science education professors) from nearby colleges and universities. Teachers could leverage these stakeholders' diverse and unique knowledge, insights, and perspectives. Ultimately, teachers may develop the competencies to design and implement effective place-conscious engineering activities, resulting in the overall success of such interventions.

Findings from the present study indicated that engagement in place-conscious engineering activities influenced positive changes in students engineering identities and attitudes towards engineering and technology. The researcher identified several factors integral to the place-conscious engineering activities students completed, as contributing to students' increased engineering identities and attitudes towards engineering and technology. These include establishing a firm connection between local community issues and classroom engineering learning; engaging students in authentic hands-on engineering design activities; and completing engineering activities collaboratively. While the overall focus of PD programs should be enhancing teachers' abilities to effectively complete place-conscious engineering activities, PD program should also aim to enhance teachers' abilities to engage students in these aspects. In the present study, they were important aspects of the place-conscious engineering activities students completed.

Recommendations for Future Research.

Based on the findings of this study, this section offers recommendations for future research. The section highlights crucial research areas pertinent to this study that have either been inadequately addressed or not addressed at all.

Conduct Similar Research with Larger Sample Sizes

The present study utilized a relatively small sample size of 20 elementary students. While the study adds valuable insights into the impact of engaging elementary students in place-conscious engineering activities on their engineering identities and attitudes towards engineering and technology, there is still a need for conducting similar studies with larger sample sizes. This is crucial because it could help ascertain the findings of this study and situate them within the broader context of findings from similar studies. Larger sample sizes could improve the overall trustworthiness of results through increased statistical power of inferential analyses (Mysiak, 2020; Suresh & Chandrashekara, 2012) and better representation of the target population (Andrade, 2020). Also, a larger sample size could allow for subgroup analysis, such as analyzing the results by gender, race, or socioeconomic status.

Expand This Study into a Longitudinal Study

Considering that this study was part of a large NSF-funded project, it would be worthwhile for the project team to expand it into a longitudinal study. The project team could continue to collect and analyze S-STEM and EIDS survey data and focus group interview data from the same participants yearly. Doing this could allow the project team to track students' engineering identities and attitudes towards engineering and technology over time, providing valuable insights into understanding the long-term impact of the intervention. The project team could also study fluctuations, stability, or progression of students' engineering identities and attitudes towards engineering and technology, providing a comprehensive understanding of these variables. Also, given that the quantitative piece of this study infers causality, conducting a longitudinal study would allow the project team to infer causality more reliably. Longitudinal studies are often considered valuable for enhancing comprehension of the causal processes that produce the phenomena being studied (Taris & Kompier, 2003).

Conduct Similar Studies with Different Demographics

Since this study was conducted with fourth graders, performing similar studies with students from different elementary grades (i.e., fourth to fifth grades) could help researchers understand the effectiveness of place-conscious engineering across different elementary grades. Similarly, while this study focused on the elementary school level, performing similar studies at the middle or high school levels could provide helpful insights into understanding the intervention's effectiveness across these three grade bands. This could allow researchers to conduct comparative analyses and uncover patterns and similarities between such populations. For example, further research may indicate whether place-conscious engineering is equally effective at influencing students' engineering identities and/or attitudes towards engineering across these grade bands. Such findings may benefit teachers across these grade bands because they could provide insights into the effectiveness of place-conscious engineering and how to conduct them.

Additionally, it would be worthwhile for researchers to study the impact of place-conscious engineering activities on populations of different demographic characteristics. These could include different geographical locations (i.e., rural vs. urban vs. suburban) and socioeconomic statuses (i.e., low-income, middle-income, and high-income). Doing this could help determine if the findings of this study will hold in these contexts.

Conduct Further Research on Students' Academic Identities

The present study arrived at inconclusive findings regarding how students' participation in place-conscious engineering activities influences their academic identities. This was partly because the EIDS's academic identity subscale did not measure students' academic identity reliably, increasing the probability of skewing the findings. Also, the items in the academic subscale had little connection to either place consciousness or engineering, making drawing unbiased inferences about students' academic identities challenging. Therefore, conducting further research that collects more survey and qualitative data would be worthwhile to further ascertain how students' participation in place-conscious engineering activities influences their academic identities. This move could also provide opportunities for assessing further the reliability of the academic subscale of the EIDS. Collecting and analyzing qualitative data could provide insight into modifying and improving the EIDS's internal consistency. Such data can also provide insights into creating a new instrument to measure academic identities. By and large, conducting further research on how students' participation in place-conscious engineering activities could provide opportunities for recollecting quantitative and qualitative data to draw unbiased conclusions about students' academic identities.

Limitations of The Study

Firstly, the study used a small sample size of 20 students, which could affect the statistical power of inferential analyses (i.e., Wilcoxon signed rank tests and t-tests) used in this study. A small sample increases the chance of such tests failing to detect actual effects and resulting in type II error (i.e., failing to reject a false null hypothesis). It also reduces the external validity of the research by limiting the extent to which findings from this study could be generalizable across different contexts. Generalizations of these findings can only apply to populations with demographic characteristics similar to those of this study's participants.

Secondly, this study was conducted during the COVID-19 pandemic. Literature shows that the COVID-19 pandemic affected people's emotional states in many parts of the world, including the US (Y. Li et al., 2021). There is a possibility that the COVID-19 pandemic influenced the physiological and emotional states of this study's participants, which can further affect their behaviors and responses to the intervention, quantitative surveys, and qualitative interview questions. Subsequently, this can skew the findings of this study.

Finally, the quantitative piece of this study lacked a control group. Experiments that lack control groups make it challenging to determine whether observed effects are solely a result of the intervention. They make cause-effect relationships somewhat ambiguous due to the lack of a baseline comparison. This could affect the interpretation of cause-effect relationships in the present study - specifically, the interpretation of findings from the first two research questions focusing on the cause-effect relationship.

Conclusion

This study explored the impact of exposing elementary students to a science curriculum incorporating place-conscious engineering activities on their engineering identities and attitudes toward engineering and technology. The study provided evidence suggesting that place-conscious engineering activities positively impacted students' engineering identities and attitudes toward engineering and technology. Elementary teachers who wish to improve their students' engineering identities and attitudes towards engineering and technology could consider introducing their students to place-conscious engineering activities. It is crucial to remember that the place-conscious engineering activities used in this study incorporated hands-on engineering activities, the engineering design process, interaction with real-world engineers, and designing and developing projects that help local communities. Educators who wish to use this study's intervention should remember that these aspects were integral to the present study's place-conscious engineering activities.

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APPENDIX

CODEBOOK

This section presents the complete codebook used to code this study's qualitative interview data. Table 11 presents the codebook, consisting of codes, their definitions, and corresponding examples of qualitative data finding each code.

Table 11. Codebook

Codes	Definition	Examples of Data Fitting Code
Hands-on	Experiences requiring students' active participation by touching, manipulating, and exploring physical objects as part of completing engineering tasks.	- BX6: "I really like how [Emma] does a lot of hands-on activities." - BX12: "We did the um, that whoever can build the highest tower" - BX16: "I like building air filters."
Societal Utility	Innovations that provide solutions to societies' challenges and improve the people's quality of life.	- BX4: "There was a big fire and there was a bunch of smoke in the air. It made it hard to breath for people. So, we made air filters for the Denton (name of town) people." - BX23: "Just um, if people are having trouble with um, for example, when um, someone's arm or leg is amputated, and they can't really walk, people [engineers] make prosthetics that can um, help them walk or grab stuff easier."
Place	Statements suggesting that students connected engineering to local places such as local/nearby places or viewed engineering as useful within their such places.	- When students discussed the engineering activities they had completed: BX12: "Um, we got to help people in Denton" BX22: "In Denton, there was the fire, like we did, it was engineering… but it's also solving a problem for them and helping them out" - Interviewer: "So if somebody asked you what engineers do, what would you tell?" BX20: "[engineers] solve problems in neighborhoods"
Collaboration	Students working together or completing a shared task to achieve a common engineering goal, leveraging their diverse perspectives, knowledge, and skill.	- BX7: "Me and BX13 (pseudonym) were a team and like, we had many ideas, but we've tried them, and they didn't work. So, then we had ah, to think of another idea…"

Engineering design	Iteratively solving problems as part of a broader engineering goal or testing and improving engineering designs for optimal performance or achieving specified requirements.	- BX5: “We had a lot of mistakes like the cardboard wasn’t on the ground or the cardboard wasn’t in the right place, the air filters weren’t in the right place, and then like the fan wasn’t in the right place, and we had to like retry and retry until we got it right - BX7: “We made a lot of mistakes and retried until we got it right testing different ideas, and generating new ideas”
Satisfaction	Having no complaints with the engineering activities undertaken, showing eagerness to continue learning engineering in a similar fashion, and hoping that other students also get the opportunity to experience engineering a similar manner.	- Interviewer: “Is there any engineering product you wish that you would get to do that you haven’t done yet?” Students: BX12: “No” BX13: “Not really” BX17: “I don’t really know any projects”
Engineering skill	Potraying engineers as highly skilled individuals capable of tackling complex problems.	- BX6: “But I would say like engineers do more than just like little things like they build cars, they find out like big problems they do a lot of things.” - BX7: “They [engineers] can do anything from making a car fly to making a bike that flies” - “Yeah, they can do anything” - BX5: “They [engineers] can do a lot of things” - BX6: “Yeah, they can do anything.”
Engineering helpful	Student statements suggesting that engineering and engineers play a crucial role in solving societal problems.	- BX20 “[Engineers] solve problems in neighborhoods.” - BX7: “They [engineers] do big stuff, and they help out the world”
Positive engineering career aspiration	Expressing aspirations to pursue careers in engineering in the future.	- Interviewer: “Do you think you would be interested in being engineers when you grew up?” Students: BX1: “yes” BX23: “Definitely”
Neutral engineering career aspiration	Uncertainty about pursuing a career in engineering or vacillating between various career options, including engineering.	- Interviewer: “Do you think you would be interested in being engineers when you grew up?” Students: BX6: “I kinda want to be a pilot, which I know involves engineering” BX10: “Um, I’m not quite sure” BX8: “Maybe an accountant, maybe an

		engineer, I don't really know."
Negative engineering career aspiration	A lack of desire to pursue engineering careers or a desire to pursue non-engineering careers.	- Interviewer: "Do you think you would be interested in being engineers when you grew up?" Students: BX9: "[I want to be] a professional baseball player"