RETHINKING ENGINEERING EDUCATION THROUGH A FOCUS ON IDENTITY, FUNDS OF KNOWLEDGE, AND BELONGINGNESS

by

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ABSTRACT

Engineering education has been rooted for years in a society that tends to neglect several student groups who are not a part of the dominant culture. A history of how engineering education has developed will demonstrate mindsets and institutional structures established that have hindered students' decision to pursue engineering and their ability to be successful in engineering. This trend has produced a broad variety of literature, initially that has highlighted this factor as a deficit for students not a part of the dominant culture, but more recently that has started to research how these students can utilize certain tools and mindsets that they do possess to reverse this trend. Additionally, there has been an initiation of how engineering education can reform to start including these tools and mindsets in how academics teach engineering. Ideas range from broadening curriculum in a way that resonates with many student groups and embraces different structures that don't solely focus on concept knowledge, but also creating the best environment for students to be successful holistically.

This thesis furthers the assets-based perspective on how engineering can encompass several concepts and infuse them within curriculum and structure to change the narrative for who is not successful in engineering. The specific concepts this paper will focus on are identity, funds of knowledge, and belongingness, just a few of the many themes research has pinpointed in playing a role in student success. Through a qualitative analysis, this paper relies on data from semi-structured interviews, surveys, and previous literature to understand how these themes can be incorporated into engineering curriculum and structure, focusing on student groups in which the common narrative has highlighted deficits within engineering. The main student group this paper highlights are first-generation college students.

A first-generation identity is explored through the lens of community cultural wealth, looking at how different students use their identity as an asset by producing a mindset that causes them to persist in their engineering education. Based on their experiences, different educational tools are suggested that utilize the wealth from their first-generation identities. The assets acquired through the backgrounds of first-generation college students are demonstrated through a short educational video, accompanied by an instructional module. These assets are called funds of knowledge and are tools these students can use to scaffold their engineering learning and be successful in their profession. Lastly, themes are discussed from a group of undergraduate engineering students experience from an immersive, sociotechnical, field-based engineering field session that focuses on their sense of belongingness before and after the field session. Sense of belongingness is considered in a variety of spaces, such as the profession of engineering, the engineering institution, the students' respective majors, their faculty, their peers, and the engineering classroom. Because students' overall sense of belongingness for the various contexts decreased following the field session, different discussion points, future work, and curriculum ideas are suggested that could be beneficial for increasing sense of belongingness.

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CHAPTER 1

INTRODUCTION

1.1 Thesis Introduction

This thesis seeks to foster diversity within engineering education by understanding the concepts of identity, funds of knowledge, and belongingness and how these concepts can help engineering educators support diverse groups of students. In order to understand how to support diverse demographics, my research seeks to explore: (1) the role identity may play in the persistence and motivation of first-generation college students to complete their engineering education and pursue professional careers within the field; (2) how funds of knowledge can scaffold the learning experiences of first-generation college students; (3) the role an immersive sociotechnical field session plays on the belongingness of undergraduate students.

The concept of identity is the focus of Chapter 2 and will be evaluated in terms of an engineering identity. The main characteristics that contribute to an engineering identity are the student's ability to see "oneself as a STEM-type of person" and the alignment between a student's personal identity (who they are, what makes them unique) and what it means to that student to be an engineer (Verdín, 2020). Specifically, the research will seek to understand how the earliest conceptions of engineering were constructed and how these conceptions relate to the student's understanding of who they are and who they can be, with reference to their first-generational status and other aspects (if applicable) of their identity. The objective of this research is to determine how first-generation college students understand their identity, particularly in reference to their generational status, but also include and analyze other understandings of identity that may stem from cultural, national, religious, sexual orientational, etc. group membership. Collins describes how the nature of identity is intersectional in the sense that the various parts of identity "operate not as unitary, mutually exclusive entities, but as reciprocally constructing phenomena that in turn shape complex social inequalities" (2015). The purpose of also including an analysis of whether or not these other identities play a role on a student's educational and professional journey is to determine how other identities may compare in importance and influence with first-generational status, considering the social inequalities produced from other identities in addition to generational status. The main type of identity that will ultimately be the focus of the research is one that stems from generational status, and whether this unique understanding of identity plays any role in first-generation college students' perception of themselves as a successful future engineer.

Funds of knowledge are the main topic for Chapter 3 and will be presented as a practical application for culturally relevant pedagogy, deviating from the academic articles the other chapters outline. Funds of knowledge draw from a couple of dominant definitions: The first definition was piloted by González, Moll & Amanti (1992) while doing participatory ethnographic research with children and teachers, hoping to draw connection between the students' everyday lives and their educational experiences. The authors termed funds of knowledge as the "collections of knowledge based in cultural practices that are a part of families' inner culture, work experience, or their daily routine" (González, Moll & Amanti, 1992). Funds of knowledge have further evolved to apply to knowledge based in work and home life activities, typically those unique to first-generation college students. Smith & Lucena (2016) performed ethnographic research with low income, first-generation college students at an engineering institution and community college in order to understand how these students use their background experiences to develop funds of knowledge and use these funds to scaffold their learning in engineering. The authors piloted a second definition for funds of knowledge more applicable to this unique demographic where they refer to "bodies and knowledge/skills working class families possess to survive and make a living" (Smith & Lucena, 2016). This expands the topic of funds of knowledge to include background and personal experiences outside those activities relevant to students' culture and family life, and includes working life activities as well.

The focus of Chapter 4 is on belongingness and will be explored from two different angles, in terms of both "personal connection and fit within engineering" (Godwin & Potvin, 2015). Research was designed to understand how the undergraduate students experience personal connection and a better fit to multiple dimensions of engineering, such as the engineering major, profession, institution, classroom, engineering faculty, and peers following their participation in the immersive, sociotechnical field session, shortened as the PIRE field session, signaling the NSF Partnerships in International Research and Education grant funding the project. This field session is a part of a larger initiative surrounding the global research collaborative RMRC (Responsible Mining, Resilient Communities). RMRC seeks to "co-design socially responsible and sustainable mining practices with communities, engineers, and social scientists" (Colorado School of Mines, 2021). The context of this research collaborative provides the basis for the sociotechnical aspect that the field session is designed to emphasize. Therefore, the premise of this research is the idea that the sociotechnical dimension of engineering can provide a more holistic outlook on the profession of engineering, thus casting a larger net on reaching more diverse student groups and creating an integrated, interdisciplinary image of what engineering can and should look like.

1.2 Background and Motivation

Research has demonstrated that identity has a large impact on a students' perception of how they will use engineering in the future. First-generation college students have a "desire to make a difference in the world and their community through engineering" (Boone & Kirn, 2016). This demographic of students plays a major role in contributing to the infusion of social responsibility into the field of engineering and incorporating a more sociotechnical perspective towards engineering solutions. These students' desire to engineer in more socially responsible ways is heavily impacted by the identity first-generation college students possess. Lucena & Smith (2016) demonstrate how first-generation college students have life experiences that blur the boundaries between humans, machines, social interactions, and calculations that enable them to understand the social and economic context of engineering problems. This context includes a variety of skills, such as the ability to design in the mist of scarcity and utilizing skills to engineer for social justice. Because of these competencies first-generation college students uniquely possess by means of their very identity, they are a true asset to the profession of engineering, especially in terms of creating a more interdisciplinary approach. They already have the background in approaching problems from an integrated perspective. Researching how their identities motivate and inspire them to persist in engineering education will allow educators to understand the relationship first-generation college students have with their definition of themselves and whether or not that definition is viewed as an asset or a deficit.

My belongingness research will benefit the Colorado School of Mines in how it seeks to evaluate the overall effectiveness of an immersive, sociotechnical summer program on increasing sense of belongingness for undergraduate students. I view this particular research as a case study with direct implications as to how the PIRE program can be reformed, if necessary, based on the results of the belongingness research. Additionally, the goal is to specify which aspects of the program increase sense of belongingness to determine how the PIRE program can be used in the future as a continued summer session. In the general context of engineering, this research is also beneficial for understanding what aspects of engineering can serve to increase or decrease a student's sense of belongingness and to what area of engineering that sense of belongingness pertains.

1.3 Previous Project Contributions

All the main contributions this thesis discusses are continuances of important assets-based concepts emerging in engineering education. Identity capitalizes on the conversation surrounding funds of knowledge and community cultural wealth. Whereas funds of knowledge emphasize the skills and tools students gather from their personal lives and backgrounds as ways to scaffold their learning, identity is also seen as a fund but not in the form of referenced knowledge, more so in how it can serve as a personal motivator and harness a mindset that causes a student to persist within engineering. This follows the assets-based approach similar to funds of knowledge by making the argument that students can adopt certain personal goals, beliefs, and values that contribute to their success within engineering in the same fashion that funds of knowledge can push students to be successful.

Samuelson and Litzler (2016) define community cultural wealth as the cultural resources that students of color develop in their families and communities and bring to engineering. The concept of community cultural wealth is very relevant to identity in that it represents motivational aspects students of color may possess that include elements tied to their identity in terms of their ethnicity. This research demonstrates how there can be motivational factors tied to a student's identity, though only in the cultural sense. My research will seek to understand if similar motivational factors exist for the first-generation demographic, and how these motivational factors are developed.

Students' sense of belongingness has been a popular topic in engineering education because of how it contributes to students' educational experiences and overall success such as increasing student retention (O'Keefe, 2013), academic achievement (Strayhorn, 2019) and cultivating engineering knowledge and interests (Smith & Lucena, 2016). Most belongingness literature has focused on how different demographics foster a sense of belongingness or experience a lack of belongingness, while this research will focus on sense of belongingness from a variety of different contexts within engineering. It seeks to explore the relationship between sense of belongingness within one realm of engineering, such as the classroom, and how this interplays with sense of belongingness in other realms, dissecting the unique way a sense of belongingness can vary among different areas within engineering.

1.4 Research Questions and Hypothesis

The following research question was developed to understand the relationship between identity and educational/professional experiences in terms of how one influences the other. This research question is addressed in Chapter 2.

> *How do first-generation college students come to understand their identity in relation to their educational and professional experiences?*

I believe that the results of my research will demonstrate that a student comes to understand identity as a positive factor for their educational and professional experiences when the concept was reinforced positively in an external sense for the student growing up, and they come to understand identity as a negative factor for their educational and professional experiences when the concept was reinforced negatively in an external sense for the student growing up. A positive reinforcement of identity means the student displays a persistence in education and desire to succeed due to a strong connection to their identity (indicating a positive external influence on identity) while a negative reinforcement of identity means the student displays a persistence in education and desire to succeed due to a disconnect with their identity (indicating a negative internal influence on identity). I believe this identity will be in terms of their first-generational status, regarding the identity they encompass from having no college guidance from a parental perspective.

While other intersectional identities may have been positively or negatively reinforced during childhood and thus play a role in inspiring or depressing a students' understanding of themselves, I believe the first-generational status of this demographic will play a role either solely or alongside other identities. Students' experiences of and identification with first-generational status are mediated by other salient aspects of their identity, such as race, gender, and socioeconomic status. Therefore, I believe the major role played by these characteristics will be in terms of enhancing either the inspiring or depressing narrative students may assign to themselves. For example, a student's negative perception of being a first-generational college student will also align with a negative perception of being a certain race, or socioeconomic status. Early negative perceptions of identity can also produce what Reid (2007) describes as a resolved identity, one in which "the individual does not focus solely on his/her reference group for appraisal; rather, their motivation is driven by what is more suitable for them as individuals". A resolved identity thus indicates a disconnect from the reference group as a means of motivation and a more personalized and self-defined understanding of oneself as a means of motivation. In effect, a positive or negative perception of identity will most likely apply to an overall positive or negative perception of identity.

The next research question was designed to understand the impact of an educational activity on the belongingness of undergraduate college students. This belongingness is in the context of the engineering major, institution, profession, classroom, faculty, and peers. This research question is the focus of Chapter 4.

How does an immersive, field based, sociotechnical field session influence undergraduate students' belongingness in engineering?

I hypothesize that the PIRE experience will ultimately increase a sense of belongingness for undergraduate students. I believe this to be the case because of the research done on belongingness and the reported ways that students express an increase in their sense of belongingness. An immersive, sociotechnical experience has elements that have been shown to highlight other non-academic dimensions of knowledge and portray engineering in a way that demonstrates social responsibility and community empowerment. With this in mind, I believe that the PIRE program's goal is to encourage students to incorporate these various elements into their educational experiences, which would thus increase their sense of belongingness.

1.5 Limitations and Biases

For addressing the research questions in Chapters 2 and 4, the main limitation of sample size exists for both data sets. For both studies, populations of less than ten were the focus of the research and thus provided limited perspectives in what the study captured. Additionally, the populations did not include a wide degree of variability in terms of student demographics with perspectives from a few unique demographics left out. This influenced the data by highlighting stories from students that may identify with only certain demographics and thus can not reflect as broad a generalization for claims the research studies suggest.

Time played an important factor for the practical application of funds of knowledge. Due to timing and constraints from actors involved and the filming crew, the video for the funds of knowledge script resulted in a scene cut from the overall filming. This scene details an important fund of knowledge and will still be included in script format, but with more time and personnel available, the funds of knowledge videos for instructors could be expanded and reference several more scenarios to depict a broad set of funds of knowledge.

CHAPTER 2

THE ROLE OF IDENTITY IN THE EXPERIENCES OF FIRST-GENERATION COLLEGE STUDENTS

2.1 Introduction

Identity can be seen as an essential part of someone's understanding of who they are, where they come from, and what they can accomplish. Various influences play a role in how someone defines their identity, and oftentimes, identity can mean different things to different people. Patricia Hill Collins discusses the concept of intersectionality as a way to highlight how the various identities people ascribe to themselves can mutually construct one another. Her explanation of intersectionality highlights the fact that "race, class, gender, sexuality, ethnicity, nation, ability, and age operate not as unitary, mutually exclusive entities, but as reciprocally constructing phenomena that in turn shape complex social inequalities" (Collins, 2015). This demonstrates the various forms of social oppression that identity groups can experience and how that social oppression can magnify when individuals are associated with multiple identity groups that typically experience marginalization within society.

Because of how identity can determine how people are treated and responded to within society by not only peers but society as a system, it plays an important role within engineering education, where certain identities are typically not seen or associated with who is an engineer. Therefore, identity is an important factor when understanding the college experiences of various types of students in order to understand how the identity they either ascribe to themselves or are labeled by society affects their educational trajectories. The most common identities that are considered marginalized within most societal systems pertain to race, gender, nationality, disability status, religion, and sexual orientation. However, generational status has recently been receiving more attention as college students who identify as first-generation have experienced the effects of intersectionality as their first-generational status overlaps with other marginalized identities that experience stigma in society.

This study examines the experiences of first-generation college students as they either are journeying through their engineering program or navigating engineering careers after graduation.

First-generation college students, defined by The U.S. Department of Education as students with parents who have not received a Bachelor’s degree, make up a significant portion of the student population. With many students entering higher education who identify as first-generation, much research has been devoted to analyzing this demographic, resulting in statistics that may suggest challenges in the recruitment and retention of first-generation college students. Of graduating high school seniors, 41.2% of the population are described as first-generation students (Boone, 2016). A study completed in 2007 by the U.S. Education Department's National Center for Education Statistics showed that of the students who enrolled in four-year public universities, only 26% of them were first-generation (Bird, 2018). According to the 2020 Equity Indicators Report, rates of enrolling in college tend to decrease with less parent education: 72% of first-generation youth have enrolled in college within eight years after high school graduation compared to 84% of youth with at least one parent who has completed some college and 93% of youth with at least one parent who received a Bachelor’s degree or higher (Pell Institute, 2020). Study results showed that about 33% of first-generation students dropped out of college after three years, while only 14% of continuing generation students dropped out (Bird, 2018). Reported statistics do not reflect the best educational outlook for first-generation college students.

It is crucial to take an intersectional approach to understanding first-generation students, as they can identify with multiple other demographics. One such mutually exclusive entity would be race, as first-generation students are disproportionately from black and Latinx families (Maltese, Lung, Potvin & Hochbein, 2013; Collins, 2015). While 25% of college students with white parents and 32.2% of college students with Asian parents identified as first-generation, 45% of college students with African American parents and 48.5% of college students with Latinx parents identified as first-generation (de Brey et al, 2019). There are multiple reasons scholars have offered for why first-generation students seem to be losing ground relative to their continuing generation peers. First-generation students do not have as high a level of recruitment or retention at STEM universities. One explanation literature offers for the low recruitment and retention for first-generation students is that the values from their community may not always be in line with higher education (Verdín & Godwin, 2015). Unfortunately, because of the overarching concerns about the challenges facing first-generation students, most research concerning this demographic has been written from a deficit perspective. A deficit perspective attributes many children’s school failure to perceived deficits within the children, their families, and their cultures (Volk & Long, 2005).

Social capital has also been analyzed as a potential explanation for the different experiences of first-generation students and their peers. Scholars in this area have taken both deficit and assets-based perspectives. Social capital is defined as the resources gained through relationships and it is based on the idea that social relations influence an individual's goal attainment (Martin, Stefl, Cain & Pfirman, 2020). Social capital can be defined from a deficit-based framework, focusing only on those social relations that seem to influence upward mobility or students to gain access to more exclusive spaces. According to the Network Theory of Social Capital, inequalities in social capital are believed to exist that allow certain students access to resources over others. It sees certain students, particularly those from certain races and socioeconomic statuses, as starting at a disadvantaged position (Martin, Miller & Simmons, 2014). This is particularly important in the context of STEM education, where certain social ties and resources are believed to be influential in terms of gaining access to educational engineering spaces. Indeed, first-generation STEM students have been found to be more likely to lack the social capital that allows them to feel connected within higher education (Verdin & Godwin, 2015).

However, some literature does highlight the beneficial attributes first-generation students can bring to their educational experiences. Smith & Lucena (2016) discuss how funds of knowledge, further discussed in the background section, can scaffold students learning experiences and increase their belongingness to their majors. Wilson-Lopez et. al (2016) also demonstrated in a study with Latinx adolescents how funds of knowledge can be used to reconceptualize learning when instructors know how to connect students' familial, community, and recreational practices to the cultural practices of engineering.

In order to research this demographic and what factors are influencing these statistics, first-generation college students need to receive more attention in engineering education literature so that academia can better equip themselves at serving the needs of this unique demographic. In this study, eight first-generation individuals who are either current engineering students or who graduated from an engineering education were interviewed to understand how their first-generation identity affected their engineering educational and professional experiences. This study seeks to understand how this population relates their first-generational status to their educational and professional experiences through interviews designed to grasp how their first-generational identity was established for them and the role that identity played in how they saw themselves as engineers.

2.2 Background

2.2.1 Identity

In addition to being intersectional, identity also has the potential to be socially constructed and self-defined. The socially constructed identity derives from external factors and "cannot be claimed in isolation and requires the participation of others to recognize that identity" (Rodriguez, Lu & Bartlett, 2018). Therefore, identity does have a component that is uncontrollable by the actual individual and instead is controlled by society. As Gee (2001) describes, "all people have multiple identities connected not to their 'internal states' but to their performances in society". As others observe individuals, they will seek to define who those individuals are and associate certain characteristics and traits to those individuals based on how they decide to interpret what certain observed identities mean. This phenomenon can be witnessed through certain factors such as stereotyping others based on what people personally understand about who others are, which is reflected in how biases, generalizations, and social stigmas exist and affect whole identities of individuals, most often out of the control of those individuals. But a self-defined identity is within the control of the individual and "refers to an internalized set of meanings attached to a role played in a network of social relationships, with a person's self viewed as, in important part, an organization of the various identities held by the person" (Stryker, 2000). Self-defined identities often make up a combination of various attributes, some physically distinguishable and others, such as sexual orientation, religion, etc., personal and not necessarily identifiable by any physical characteristic. Another important component of the self-defined identity is how individuals can redefine socially constructed identities in the internal sense to mean whatever the individual would like that identity to mean. This often plays out when individuals "identify themselves with (and against) these socially-constructed types in the various domains of their everyday lives'' (Holland & Lachicotte, 2007). Individuals may resist the socially constructed interpretations of their identities and self-define the specific identity to look like something else to them instead of how that identity may be socially perceived.

2.2.2 Funds of Knowledge

Due to the socially constructed identity that often can be placed on certain demographics, some students can be perceived negatively in the educational system, especially students that come from demographics where deficits are typically highlighted. In the engineering industry (which includes the academic and professional environment), these negative perceptions are targeted at individuals from the minority populations within engineering. These populations most always include racial minorities and low-income students, which are often (but not always) correlated with first-generation status. As discussed in the introduction, intersectionality also plays a role in the overlapping identities that contribute to deficit perspectives towards students from minority groups, so students who may be a racial minority, low income, and first-generation may face negative perceptions tied to all of their identity groups. This deficit perspective has influenced the value of certain types of knowledge and the supposed inadequacy for other types not based in the traditional engineering mindset. Looking at the culture of engineering, socialization that reinforces norms and beliefs about the world rooted in depoliticization and meritocracy causes knowledge from a privileged and elite standpoint to prevail in academic and professional settings (Cech, 2013). This superior recognition of the types of knowledge that are a part of the dominant culture of engineering institutions leaves other forms of knowledge excluded from the classroom, sometimes unrecognized by the very students who possess them. However, recent literature highlights a transformational, assets-based approach towards these nondominant funds of knowledge by focusing on the strengths that students possess when they come from a background not rooted in the dominant form of knowledge represented within engineering culture.

One of the most crucial of these assets are funds of knowledge (FOK), which are collections of knowledge based in cultural practices that are a part of families' inner culture, work experience, or their daily routine (González, Moll & Amanti, 2009). The concept of "funds of knowledge" was first piloted by academics when doing participatory ethnographic research with the conviction that the K-12 educational process could be enhanced when teachers learn about their students' everyday lives. By understanding how a student's household and community influence him/her, they confirmed that teachers could learn how these students make sense of everyday life (González, Moll & Amanti, 2009). González and the other authors conducted a study where teachers interviewed students on their family background and everyday lives in order to understand how things like family history, household life, and social networks served as funds of knowledge in each student's life, including how they thought and understood the world. The teachers then used this information on the students' FOK to contextualize their learning. Contextualization is defined as making meaning and connection with school and students' lives (González, Moll & Amanti, 2009).

Research also confirms the influence of FOK, particularly as it relates to tinkering knowledge and mediational skills, as a way to scaffold concepts that first-generation students currently learn in engineering (Verdín, Smith & Lucena, 2020). As a result of incorporating FOK into their engineering education, first-generation students perform better in their engineering coursework and have more certainty about graduating (Verdín, Smith & Lucena, 2020). Further research demonstrates how FOK support minority students' interest in engineering, self-efficacy beliefs, and their decision to major in engineering (Verdín, Smith & Lucena, 2021). Another study that looked at ethnographic data from six first-generation college students concluded that funds of knowledge can be converted to capital that is beneficial for engineering education. Students demonstrated technical competencies from tinkering knowledge they acquired from work and home, and they also developed socio-behavioral competencies from funds of knowledge such as reading people and perspective taking (Verdín, Smith & Lucena, 2021).

2.2.3 Funds of Identity

Just as funds of knowledge demonstrate the importance of students' personal lives to providing meaning and context to engineering concepts, funds of identity emphasize the importance of students' identities when they actively internalize family and community resources to make meaning and to describe themselves (Esteban-Guitart & Moll, 2014). These identities are both socially constructed and self-defined with internal thoughts and beliefs shaped by the external environment, which in turn are shaped by everyday practices. The concept of funds of identity is described as having four components:

(1) Identities are made up of knowledge, skills, practices, people, and resources that are encountered in everyday life. People identify with others in the same roles, professions, interest groups, and other various social functions where people congregate around a central focus.

(2) Artifacts can be internalized as part of identity, as certain symbols and signs have significance in defining where someone comes from and/or what they believe.

(3) Social interactions help individuals form their identities around various knowledge, skills, etc. that they possess. Individuals start to learn what their identities mean as they observe peers in the same identity groups.

(4) Identities are therefore social as individuals assign certain characteristics and beliefs to what a certain identity means, and those tools serve as the funds of identity that individuals can lean on to make sense of all areas of their lives, including their education (Esteban-Guitart & Moll, 2014).

Esteban-Guitart and Moll (2014) offer various ways students can recognize their funds of identity through activities like creating relational maps called "significance circles" or self-portraits that include various depictions of the cultural, symbolic, and social components of how someone defines themselves. In one study by Saubich and Esteban-Guitart (2011), a 12-year old Moroccan girl from Spain illustrated her identification with henna through a self-portrait and the authors designed teaching activities developed through this particular fund of identity. Since we learn best when something can be tied to previous knowledge, funds of identity can provide teachers with a framework in which to design lessons and choose the best instructional material that capitalizes on connections students can make with their own identity, including culture and experiences. When instructors can understand what references are most appropriate for students, learning can become more individualized and personalized. Research proves the importance for students of instructors who appear to personally invest in them and how this increases their feelings of belonging in the engineering classroom (Rainey, Verdin & Smith, 2021).

Funds of identity are the connection between identity and funds of knowledge in how skills, culture, practices, and other expressions of one's personal life are internalized to actually become a part of how people define themselves, and how they can be beneficial for supporting a students' understanding of engineering when they are included in classroom learning. While it is apparent that our self-defined and socially constructed identities can play a large role in many facets of our lives, understanding the role they play in our educational and academic path is a topic that deserves further exploration because of how they can be connected to current learning experiences. Long term, this can benefit students in terms of graduation certainty, self-efficacy beliefs, and feelings of belongingness.

2.2.4 Community Cultural Wealth

Research on community cultural wealth also highlights the impact one's cultural identity has on their educational experiences from an assets-based perspective. Community cultural wealth refers to the "the talents, strengths and experiences that students of color bring with them to their college environment" (Da Graca & Dougherty, 2015). Yosso's Cultural Wealth Model expresses six ways this wealth is manifested in a student's environment: aspirational, familial, social, linguistic, resistance, and navigational (Yosso 2005). *Aspirational capital* exists because of the career goals and future a student hopes to accomplish. It refers to a resiliency students' can possess to see past their current circumstances and still have goals and dreams for a different future. *Familial capital* focuses on kinship and the community ties one has with their immediate circle. Familial capital propels a student to have deeper motivations that are connected to those around them, such as their well-being, and a camaraderie in the mist of common issues. *Social capital* has been studied and emphasized beyond community cultural wealth and refers to the community networks and connections people have that can provide emotional support, as well as reassurance and preparation. While social capital is usually highlighted when social networks are well established within the dominant society, it is just as imperative for students who may not feel their social circles are as highly regarded. Research especially highlights the impact of social capital on first-generation college students. Though they may access their social capital more frequently and have a smaller group of individuals, research still suggests that these students are successful when utilizing these networks (Martin, Abdiel, Alvarez, Pfirman & Miller, 2014). *Linguistic capital* refers to communication skills obtained through more than one language, emphasizing the ability to establish relationships cross-culturally and successfully maneuver a bilingual environment. *Resistance capital* emphasizes the importance of knowledge and skills obtained through resisting inequalities and challenging barriers. Users of this capital take advantage of verbal and nonverbal tools meant to send social messages that resist the narratives tied to certain identity groups. Individuals learn how to successfully reject the status quo through different forms of oppositional behavior, especially subtle. Lastly, *navigational capital* highlights the ability to successfully navigate through different social systems and institutions alien to what an individual may have previously experienced. As another type of resiliency, navigational capital focuses on invulnerability, meaning individuals know how to compartmentalize and maintain success and motivation despite stressful circumstances, barriers, or social stigmas that threaten to challenge the accomplishments they wish to achieve. These forms of wealth are pinpointed to a student's culture, emphasizing the utilization of these forms of wealth as a tool for minority students.

This chapter builds on this model by understanding wealth tied to a first-generation identity for engineering students. This approach has previously been taken in a number of other studies, most relying on qualitative data collection from interviews and focus groups, but the studies focus on cultural identity with mostly a representation of Latinx and black students. These studies demonstrate the usage of the six types of capital by these students in navigating their engineering careers (Denton et al., 2020). Adopting the same assets-based approach, this study uncovers the ways in which a first-generation identity can motivate a student to succeed in their education and how community cultural wealth can translate to a first-generation identity. It seeks to answer the following research question:

> *What role does identity play in the educational and professional development of first-generation college students?*

By adopting an understanding of identity that expresses both the self-defined and socially constructed identity, the study relies on the concept of funds of identity by uncovering what a first-generation identity means to each student. Merging funds of identity and funds of knowledge together may mean that first-generation college students can access a repertoire of wealth that can be used to reinforce persistence and resiliency towards completing an engineering education and succeeding within the industry.

2.3 Methods

2.3.1 Interview Questions

Open-ended interview questions were designed to reveal how a first-generation identity could be prevalent and impactful for students throughout their childhoods, educational experiences, and (if applicable) professional journeys after graduation. The questions outlined in Appendix A were posed to the interviewees who identified themselves as first-generation college students. There were five segments outlined in the interview process, each segment focusing on a different aspect of the students' personal, professional, and educational experiences. The interviews lasted from 45 to 60 minutes.

2.3.2 Interviewee Demographics

A total of eight individuals who self-identified as first-generation college students were interviewed. Selection was based on a response to different polls and surveys marketed towards (1) the Colorado School of Mines themed-learning community Nucleus, which is dedicated to the first-generation college student demographic; (2) the Colorado School of Mines multitude of cultural organizations dedicated to students of a particular ethnic background, gender, or sexual orientation, since intersectionality is common for a first-generation identity with other minoritized demographic groups; (3) the Colorado School of Mines Humanitarian Engineering program. Eight individuals total committed to the interview process and signed Informed Consent waivers to allow the sharing of their personal stories within this study. The general demographics of this interviewee pool is outlined in Table 2.1 below.

Table 2.1 First-Generation Engineering Student Interviewee Demographics

Student Acronym	**Ethnicity**	**Gender**	**Educational Level**
AR	Puerto Rican	female	Undergraduate student
AA	Caribbean	male	College graduate
Y	Mexican	female	Undergraduate student
G	Mexican	female	Undergraduate student
D	Black	male	College graduate
B	White	female	Graduate student
AG	Hispanic	female	Undergraduate student
MM	Mexican	female	Undergraduate student

2.3.3 Data Analysis

This study is a qualitative assessment of the role identity plays in the educational and professional experiences of first-generation college students. Eakin (2018) references several analytic strategies that are useful for interpreting qualitative data, one of which is coding. Coding was used to relate each individual's understanding of their first-generation identity with a form of community cultural wealth, seeking to understand if community cultural wealth could be translated to apply to a form of wealth applicable to a first-generation identity and whether other themes emerged that suggested a different form of wealth that students could use as a way to persist in their engineering education. The analysis follows both a deductive and an inductive approach. Deductive analysis was utilized in that a concept was uncovered, qualitative data was collected, and that data was analyzed for themes that either supported the original concept or suggested a different concept altogether (Azungah, 2018). Because this study starts with the concept of community cultural wealth, it follows a more deductive approach in that certain forms of wealth were already outlined and used to interpret the interview data. When a different concept emerged, however, this followed an inductive analysis because themes were uncovered without an originating concept to which to tie the themes. Previous studies that have analyzed community cultural wealth for engineering students have also followed a qualitative approach. While future work can explore measures of quantitative measurement, there is an implication that students' voices can be lost in the process and certain aspects of the data may be unquantifiable. Quantitative analysis may not account for student's overlapping their usage of the different forms of capital and the possibility of a new capital emerging, and this makes community cultural wealth items not suitable for factor analyses that would be involved in developing a quantitative scale (Denton et al., 2020).

2.3.4 Limitations

Like all studies, this study has limitations in regards to sample size of students interviewed and diversity in the demographic make-up of the interviewees. The most underrepresented demographics were male, white, and Asian first-generation college students, as there were few or no students who represented these demographics therefore not allowing much area for comparison of perspectives within these groups. Additionally, there were few students who discussed coming from a high socioeconomic background; only one student discussed her family's financial situation suggesting that they came from a high socioeconomic background after she left home and enrolled in college. However, this student did not grow up with this particular background. The absence of students who grew up with a high socioeconomic status also does not allow for pinpointing differences that are just due to a first-generation identity as opposed to a low income and first-generation identity.

2.4 Results

2.4.1 Familial Capital

Familial capital describes "those cultural knowledges nurtured among familia (kin) that carry a sense of community history, memory and cultural intuition" (Yosso, 2005). A part of being a first-generation college student means that neither parent completed higher education at a Bachelor's level, so many students' narratives included witnessing challenges faced by a parent because of not completing a traditional Bachelor's education. AA commented in his interview regarding his mother that she "definitely had an appreciation for education and wished she was able to do more but couldn't because of finances and the kids. She never had a college opportunity and that was why she pushed". AA mentioned his mother as the main influencer and motivator in his decision to go to college, stating a few examples of how "via phone calls, Mom was crying to for me to return to Caribbean so that I could go to college." He said, "I didn't feel I had the luxury to not like my major, knew the sacrifice she made" (AA). This narrative has many themes suggesting AA's usage of familial capital, which suggest that "our kin model lessons of caring, coping and providing, which inform our emotional, moral, educational and occupational consciousness" (Yosso, 2005). According to AA, his mother showed investment in his education, emphasizing her reactions to his educational decisions, and he stated how he "made a commitment and needed to finish." A huge part of AA's reasoning for continuing on in his education, despite challenges that came up or his own personal feelings of not wanting to be there sometimes, was that his mother cared so much about college. And from his narrative, a lot of her concern for a college education came from her witnessing how career and money earning potential can be limited without a college education, tying socioeconomic factors into the identity of being first-generation. This is not to imply that AA's narrative described a desire to earn money or achieve a certain type of career. What really motivated AA was his mother, and she provided him with familial capital.

G showed a sense of familial capital as well, also as it pertained to her mother. She commented in her story how she "didn't really have general idea of what I wanted to do" but "knew I wanted to go to college because Mom would repeat that if I wanted to have better conditions… [I] knew go to college but not exactly what I wanted to do." G added, "Mom felt life was hard because she didn't go to college, she just wanted something different for us." G's direct motivation for going to college was mostly because of her mother, stemming from the experience of being first-generation. Her mother stated how she felt life was hard because of a lack of higher education and, similarly to AA's mother, she pushed her children to go to college so that they would not experience the same conditions both mothers felt were tied to a lack of higher education. While G did express other types of capital as a part of her decision to go to college, there is definitely a strong sense of familial capital present in her narrative. Aside from the experiences of being first-generation, G showed an admiration of who her mother is, portraying somewhat of a motivation to go to college not because of what her mother experienced, but because she admires her mother and thus would heed her advice. As G described her mother being the most influential being in her decision to go to college, she stated "she was really intelligent...makes different things every day and is still successful, couldn't believe she didn't know how to read and write so long... education was very important to her." She said she was "glad to have options for future, options to dream. Mom didn't have that option, just had to dream of work" (G). Yosso (2005) discussed that "aspirations are developed within social and familial contexts, often through linguistic storytelling and advice (consejos) that offer specific navigational goals to challenge (resist) oppressive conditions". G's mother provided her with aspirations meant to challenge current conditions. As G described having "options to dream", she expressed her ability to aspire outside of current conditions based on the desire for education that her mother instilled within her. AR reflected similar sentiments of having a motivation tied to her family when she described the most influential beings in her decision to pursue college. She talked about her parents and how she "wanted them to be proud of her" and how "seeing their hard work and sacrifices to give me the life I have...want them to see me graduate" (AR).

Previous studies also cite the importance of familial capital as a tool for students to persist in their engineering education. Among a few are Coronella (2018) who discussed students' persistence in their education stemming from needing to support family members, Tolbert (2017) who mentioned how parents support STEM interest for students while growing up, and Rosbottom

(2016) who talked about younger siblings serving as the capital because students desire to be a role model for them. These studies highlight the wealth obtained from family in how it causes students to continue in their education, receiving direct motivation from their family.

2.4.2 Aspirational Capital

Aspirational capital sees past current circumstances and has high aspirations for the future (Yosso, 2005). Typically, familial capital can function as a form of aspirational capital as well because students used their parent's experiences to help them aspire to attend college. In MM's story, she displayed aspirational capital as she described her journey in her college education. Her story is different in that she did not necessarily pursue college because of witnessing limited opportunities due to being a first-generation student. While she did describe growing up poor, she didn't speak to her childhood experiences in terms of financial struggles. Her parents always supported her schooling, and she talked a lot about how she loved school. She got paid for good grades and her parents did not support her getting a job while in high school, something that is not always typical of students from a low socioeconomic background. And later in life while MM has been in college, she witnessed her family move into a higher socioeconomic status, not dependent on furthering education but by her mother being so good at her job and being able to obtain a higher position in her field with a better salary. MM's desire for a college education did not stem from feeling like without one, she would not be able to support herself financially or access certain careers, but instead stemmed from her peers in high school and their educational prospects. She discussed how she came upon her decision to pursue engineering at Colorado School of Mines:

> "[I] always knew I would go to college, wasn't a choice, just happened upon Mines...I was in marching band in high school and a [really smart peer] was doing engineering and was going to Mines so I googled the school and found out how easy it was to apply...didn't think I would get accepted and at first didn't want to go because I didn't know anything about Colorado. When I came to visit I sat in on a SWE (Society of Women Engineers) meeting and had a personal tour and the tour guide was very nice and let me know how she didn't have her major all figured out before she came to Mines...she was relatable and

> showed Mines to be accessible, she became my peer mentor. [I] fell in love with how nice people were and how small the campus was" (MM).

MM's decision to come to Mines and study engineering at first was centered on her community networks as opposed to family, and later within her story, she described a driving force that suggested aspirational capital. In MM's story, this aspirational capital appeared as a desire for excellence and exceptionalism. When she first got to Mines, MM confessed that she didn't feel like she knew a lot, sometimes feeling confused in conversations or like it was harder to connect with people. However, MM had a form of aspirational capital that caused her to not only desire to know as much as others knew, but to go above and beyond, becoming a resource to others and a campus leader for obtaining resources. MM reflected on her college experiences, describing how:

> "since I didn't know anything coming in I got very involved in resources because I saw the importance of them...I got really involved on campus...became big advocate for a lot of stuff (peer mentor, peer educator, working for Title IX)...sometimes I let seniors know of stuff that exists, being so involved made it a little harder to make friends...I was really big on being informed...every day I commented on at least one campus resource, didn't get involved in social stuff on campus just resource related stuff" (MM).

When MM cited negative experiences she had during college, they involved examples of feeling like there was a lack of support or sensitivity directed at first-generation students; therefore, MM desired to rise above that narrative, becoming an information guru so that she was equipped with all of the resources she felt were hard to obtain at first. When her parents' socioeconomic status began to rise, MM described moving to a nicer neighborhood and how "a lot of people at my school were going to college for engineering and all the smart people were doing it...as a first-gen, I felt I needed to do something impressive at college...had to do something in STEM...engineering makes the most money" (MM). While MM did not necessarily associate her desire to go to college specifically with making a lot of money, she related the idea of pursuing a career that made a lot of money as doing something impressive, which is truly what she desired. And it is not only her first-generation identity that inspired MM to aspire for excellence and exceptionalism but also her female and Mexican identity. She talked about how engineering raised her interest in high school because she was told it needs more girls, and how pursuing engineering helped MM to feel like she was really making a difference. She talked about how she was “representing my people...I’ve got to be impressive, show off, show we are capable” (MM). As with familial capital, aspirational capital is also reflected as a motivational form of wealth in literature on engineering education. Samuelson & Litzler (2016) discussed how African American and Latinx students demonstrated aspirational capital in pursuing engineering in terms of grit, which causes students to stay focused on long term goals with passion and perseverance. Chavez (2018) also presented an interesting application of aspirational capital with an example of a student who aspired toward a particular future endeavor motivated by the student’s current circumstances where her family struggled to receive assistance for Latinx immigrant families.

2.4.3 Resistance Capital

Resistance capital refers to those “knowledges and skills fostered through oppositional behavior that challenges inequality” (Yosso, 2005). In terms of first-generation status, resistance capital appeared as a desire to change a narrative. Some students displayed a motivation to pursue higher education simply to not be what they believed was society’s narrative of the future of a first-generation college student. Resistance capital has an intersectional affect, as many students were resisting narratives assigned to identities beyond being first-generation, such as race, gender, or socioeconomic status. In D’s story, he began his journey to higher education as a response to “getting out” (D). In the town where D grew up, he described career opportunities as being limited to the military, “doing the same ole same ole” (D), or going to college. As D described peers in his town, he mentioned “coming from broken homes...growing up poor” (D) and how he didn’t feel like he related to many peers he grew up with. D had a desire to not end up doing the “same ole same ole” and rewrite the narrative that he believed most people in his town followed. When D came to college, he was very ambitious about finishing early. Aside from that, he was determined to build an entire set of marketable skills from his other interests, such as public speaking and business, while working towards his engineering degree. As D reflected on the downsides of his college experience, he related many of his problems to him getting in his own way. He stated how he “was unwilling to ask for help...didn’t know who to ask it of...was naïve and had a gap in understanding but wasn’t doing anything to meet people in industry but yet was overconfident that I would graduate and be just fine” (D).

D's usage of resistance capital mirrors how Yosso (2005) described black mothers as teaching "their daughters to assert themselves as intelligent, beautiful, strong and worthy of respect to resist the barrage of societal messages". To D, appearing lost, confused, or needing help in his education from certain people would accept societal messages that made D feel incapable. D demonstrated this same type of capital in his motivation and grit towards wanting to go above and beyond, yet not through the dominant systems in place, but by relying on his own navigation and understanding of the educational system. While he stated the downside of this thought process, he utilized it within his college journey and it served as motivation for propelling him to graduation. D embodied what he considered an "anti-victim" mentality that manifested in his commitment to not make himself appear vulnerable. He reflected how he "felt like I was waiting for someone like me to come by and pick me up...wasn't willing to get support from people who were offering because they didn't understand where I was at" (D). Instead, D would be his own support system and make sure he excelled in whatever he pursued, whatever it took. D described himself as "running away from the bad thing someone thought could happen to me" (D). D's story suggested that he used resistance as a means to succeed. As he thought about his own definition of what his identity meant to him, he made sure that he was not pursuing sports for his success, as he described this being a common pathway for people with his identity, and was "going to college without any help" (D).

Examples of resistance capital can also be found in literature. One study from Cortes (2017) talked about students using resistive behavior to combat rules, such as sneaking food into the library, that were hindering to a student's success. These students wanted to be able to study longer so sneaking food into the library was their way of using resistive behavior towards instances where they felt barriers existed to their success. Samuelson & Litzler (2016) discussed, among other studies, the motivation of resistance capital that can cause students to persist for the pursuit of social justice. Rainey, Verdín & Smith (2021) also discussed minoritized student's motivation for engineering that tends to focus on careers involving social justice.

2.4.4 Social Capital

Very similar to familial capital, social capital extends beyond just the family network to include all community networks that offer resources and emotional support. While both AA and G described using familial capital, they were also utilizing social capital. In contrast, students such as D who felt disconnected to their communities, did not use social capital to motivate themselves forward in their education. Additionally, students who did not specifically state their family as their main source of motivation for going to college did mention other community influences as motivation for pursuing education. While MM discussed smart peers as influential for studying engineering, AR described the general community in Puerto Rico as “encouraging their kids to go to college even if they couldn’t afford it...value good education and good life for kids” (AR). AR always knew she was going to college because she wasn’t around many influences that encouraged anything else. She talked about much of her graduating class going to college and how it “felt like the right thing to do” (AR). Even while in college, AR expressed her support systems as being her community networks, whether it was her volleyball team or the peers she studied with for exams. The positive experiences that stuck out to her involved “staying up all night studying with study groups then taking the exams and getting good grades...that was a good experience because I realized hard work paid off...I was going through the same experiences with other peers and having the support” (AR). In fact, AR did not cite any negative experiences with her communities while studying at Mines. Y also cited her community, including family, as the most influential presences for her decision to go to college. One perspective she gave on higher education was that it was a way to “professionally serve my community” (Y). While in college, she studied alongside other first-generation college students who she describes as “big support because they are good friends, they are empathetic...we learn together, if someone does not understand a topic we all teach each other, we are a good group” (Y). Similar to AR, Y felt a strong motivation to continue along her educational journey because of the understanding and supportive peers she was surrounded by. She also described how her perspective on engineering did not change while in college because she was around so many different types of people studying engineering and pursuing many types of careers. Y saw her engineering community as diverse and inclusive. Social capital is discussed many times in academic literature, beyond the umbrella of community cultural wealth and as it pertains to a first-generation identity. Both deficit and assets-based perspectives have discussed the usage of social capital by first-generation students, as was summarized in the introduction.

2.4.5 Other Forms of Capital: Similarity Capital

Beyond the existing forms of capital associated with community cultural wealth, the ethnographic data suggested a new type of capital. Whereas the students who utilized the other forms of capital suggested some source of motivation tied to their family, community, aspirations, or decision to reject the narrative they believed was associated with their identity, a couple students embodied an orientation to their lives that suggested they did not see themselves as different at all. Though they identified as first-generation college students, their understanding of their first-generation identity did not emphasize differences between themselves and students whose parents attended college. In pursuing their college education, they appear to be drawing on capital that allows them to feel just like another student. They didn't emphasize barriers or challenges tied to their first-generation identity. Therefore, their capital seems to be one of *similarity capital,* which we can define as pursuing one's goals indifferent to or unaware of barriers or challenges tied to a minority identity within the dominant culture. Prior to college, B discussed how she loved learning and had a "huge desire to learn, not that I knew I needed to go to [college to] be successful." She continued with, "outside of my parents no one had gone to college but was doing just fine where they were...education gave me the power to make a difference, not something that would make me more successful" (B). It is worth noting that B is white, which means that it may be easier for her to identify with mainstream students. Even after entering college, B did not demonstrate any sense of aspirations, community or resistance motivating her to continue in her education, though the desire to make a difference can signify a type of resistant though not tied to an aspect of identity. In fact, she did not feel entitled to many resources that were for first-generation college students. She described the first-generation community at Mines with "a lot of the support has mostly been directed towards minorities…I remember a group talking to first-gen and transfer students and most of them were non-white" (B). B's lack of desire to identify with the first gen community may stem from her own identity as white. B attributed most of her negative college experiences to the fact that she is a non-traditional (older) college student living off campus with an entire life aside from college, which caused challenges when trying to coordinate schedules for group projects and attempting to attend professors' office hours.

For AG, she didn't even recognize growing up that she was first-generation. In her decision to go to college, she talked about how "I figured I should just go to school because I had the ability to and assumed a lot of people I went to school with would also go to college, though it was not the case" (AG). While AG did express that cost was a barrier, she also mentioned influences from her family and wanting to be a role model to other girls working in the sciences. But once AG got to college, her story reflects more of an understanding and an appreciation for her first-generation identity. She found a first-generation community at Mines and stated how “if I hadn’t been a part of it, I wouldn't have realized the strong first-gen community” (AG). Her experiences at Mines caused her to recognize her connection to other identity groups and use them as support systems. She mentioned how she “doesn’t see a huge difference between myself in comparison to the rest of the student body, we’re all the same...I do believe first-gen students’ band together though” (AG) which suggested that she felt apart of the general study body but recognized the camaraderie she can feel with others in her identity group. She also mentioned being a part of MEP, the multicultural engineering program at Mines. AG later reflected that she does realize how “being a huge female minority in classes makes me feel different about the path I’m taking” (AG), but she can’t recall negative encounters that have to do with her first-generation identity. Her story revealed that other forms of capital she may utilize are not tied to her first-generation identity and that rather any difference she feels is from other parts of her identity. In coming to terms with her first-generation identity, she does not see it as a hindrance, barrier or form of challenge in her educational journey.

2.5 Discussion

Among the eight interviewees, the most common form of capital was familial capital, and to some degree social capital as well, because most individuals reflected a motivation tied to others around them, especially those they respect and value. Research reflects the influence family members can have because of their support and helping students foster higher degrees of belongingness to their classes and major (Boone & Kirn, 2016). This can be a helpful tool for fostering grit and persistence for students in their classes (Verdín, Godwin, Kirn, Benson & Potvin, 2018). College educators can take advantage of this powerful capital by including more events, learning experiences, and opportunities for students to use their social networks, especially family, to scaffold their education. Some potential ideas for using this capital can be allowing more freedom within the project space for students to involve networks, communities, or industries more in line with their personal spaces so they have the potential to capitalize on their familial and social capital. If someone’s family owns a community garden, students may design an engineering project that allows them to focus on a problem involving their family garden. This flexibility is most beneficial in terms of senior design projects or summer enrichment experiences where students have more options in how they can approach projects and what they choose to focus on.

Other potential areas could be in terms of lab assignments. Instructors could explore more ways to allow students to study the environments around them, allowing their personal networks to be more involved in their educational spaces. While one assignment may instruct students to look for low impact development, defined as environmental structures that have the added benefit of improving water quality in runoff, at their institution, a more identity-based assignment could instruct students to look for low impact development in their own neighborhoods and if they can't locate it, make suggestions as to how they would want to implement low impact development. Allowing students to focus their learning on things that matter to them can connect their education to their personal lives, providing more meaning and belongingness to their major.

While students who relied on familial, aspirational, social, and similarity capital all seemed to describe a childhood rooted in positive experiences, the students who used resistance capital reflected somewhat of a tense upbringing. This could potentially be detrimental for students relying solely on this type of capital because it may cause them to reject resources and helpful tools in order to not appear vulnerable or lacking. This presents a unique challenge for educators who should be cognizant of this form of capital in how they approach students who may be using resistance capital. Offering students any form of support who may be using resistance capital may need to be strategically done in order to not appear as though support is being offered because students are seen as lacking.

Another interesting observation was the distinction between white first-generation students from the general body of first-generation students. Because of the intersectionality of exclusionary social structures and students' identities, it may seem that first-generation students are nearly all minorities, but this is not the case. Making this assumption can cause other students to feel excluded from resources. Research discusses this trend and how "trying to understand the significance of class background for engineering students by studying racial and ethnic minorities misses many poor white students, who are also often the first generation of their families to attend college but lack the same networks and support groups utilized by their peers who are also students of color" (Smith & Lucena, 2016). Resources and support systems meant to target first-generation college students need to be inclusive of all the types of identities that represent this demographic. White students should be able to feel these resources are accessible to them and that they are entitled to them as first-generation students. College educators can be mindful of this demographic as well by representing the stories and experiences of this unique demographic so that first-generation white students feel welcome to participate in first-generation networks and take advantage of the opportunities they present.

Finally, the concept of similarity capital offers a novel way to value students' abilities to identify points of commonality with more mainstream students. While the literature on community cultural wealth, funds of identity, and funds of knowledge all emphasize the value of students capitalizing on their *differences* from dominant engineering culture, these interviewees draw attention to the power of identifying similarities and downplaying differences. They remind us that these practices, too, are key for navigating educational and professional systems that would otherwise exclude them. While the small number of interviewees in this study caution against drawing large generalizations, the data do suggest that these "blending in" practices may be more appealing or more possible for first generation students who are white.

2.6 Implications

This study is useful for guiding future instructional methods and university programs and events. It can help educators create a learning environment more conducive to what is important to first-generation college students. However, it is merely a small piece of the myriad forms of capital this demographic uses. Future work should look towards further understanding distinct pools within the first-generation population, such as students from white and Asian racial groups, students with a first-generation background but perhaps a high socioeconomic status, and male first-generation students. These groups are not typically studied because most of them are usually not the face of the first-generation college student, but they can easily be forgotten because of how they differ in terms of the typical intersectional identities with a first-generation identity. It would be beneficial to see what forms of capital these identity groups depend on and how learning can be directed towards their experiences. It would allow resources and programming targeted at first-generation students to be more inclusive of the unique populations they serve.

Additionally, targeted learning benefits students from all types of backgrounds by allowing them to use their own forms of capital to scaffold their learning. In research about funds of identity, educators used these funds practically by guiding students through mapping out their own identity. In terms of the type of capital it provides, identity can also be mapped for students with different reflection exercises that utilize future time perspective. Research defines one segment of future time perspective, perceived instrumentality, as a way that students can relate the usefulness of their current tasks to their future goals (Boone & Kirn, 2016). This can be helpful for students by understanding what personal tools they use to push their understanding of their current path to who they hope to be in the future. What funds of identity can help educators achieve is fostering the grit necessary to help students remain resilient and persistent towards completing their career goals. Instead of just focusing on the conceptual grasping of engineering, educators can include a different type of capital that promotes student success by also focusing on why students want to be engineers, tapping into that motivation from both past experiences and future aspirations.

These forms of wealth from identity can also be a great way for educators to connect with their students. For students more reliant on aspirational capital, educators can capitalize on the importance of the student's future goals on their educational success and could direct the student towards goal-oriented activities. Similarly, students who use social capital may be interested in different professional organizations and programs that can foster community and social support. Even at the beginning of a course, instructors could have students reflect on the forms of motivational wealth they use to persist in their education and if they are willing to reflect on this with their instructor, the instructor can better prepare on how to individually support the student.

2.7 Conclusion

This research applies the community cultural wealth perspective to a first-generation identity for engineering students and demonstrates the asset of understanding how first-generation students define their identity and use that identity to stay focused in their educational pursuits. The most prevalent forms of wealth described by first-generation students in the interview data were social capital from connections, community, and family, which is described as familial capital. Additionally, aspirational capital, which gave students the ability to have a strong desire to pursue and achieve beyond what they may have been exposed to growing up and resistance capital, which allowed students to reject negative connotations tied to their identity, were forms of wealth described as well. Another form of wealth called similarity capital was defined and describes a first-generation student's ability to see themselves as another student without thinking of barriers and challenges that are tied to their first-generation identity.

It is beneficial for educators to integrate more identity-based learning into their platforms so identity can be used as a fund for not necessarily understanding engineering concepts, but for persisting towards graduation and progressing through the engineering workforce. While there are various ways first-generation students use their identity in relation to how they choose to journey through their engineering education, research shows the powerful way their identity can aid in their educational endeavors. If we approach identity from a wealth perspective, we will see more first-generation students recognizing the forms of capital they have available to them and using that capital to be successful. This study ties together the themes of funds of knowledge, funds of identity, and community cultural wealth to propose how identity can be a fund, from a first-generation perspective, adopting assets defined in community cultural wealth that students can use to persist in their education. Where funds of knowledge describe different skill sets first-generation college students can use from their background, identity is used as a form of wealth by understanding how it impacts a student's outlook, thus dictating how they will navigate their college education and career thereafter. The benefit of capitalizing on all of these assets-based approaches together is to address different areas of the college experience that can aid in a student's success, which include both skills they can use and mindsets they possess. A first-generation identity from a community cultural wealth perspective explores how learning can support these mindsets and strengthen the educational experiences of first-generation, engineering, college students.

CHAPTER 3
INCORPORATING FUNDS OF KNOWLEDGE INTO ENGINEERING CURRICULUM: A PRACTICAL WORKSHOP

3.1 Introduction

Following the piloting work of González, Moll, and Amanti as well as a slew of multiple other researchers with studies done on students focusing on how their funds of knowledge scaffold their education, this chapter seeks to explore how to practically apply funds of knowledge into the engineering classroom. In the first section, a script is outlined that accompanies an educational video depicting different funds of knowledge and how students use these funds to apply to engineering coursework and projects. The video can be a tool for both engineering educators and students, the earlier of which can see how funds of knowledge can be applicable to the classroom and the later can understand how to relate funds of knowledge to engineering knowledge. In the sections following the script, a few workshop tools with examples are suggested as a way for educators to incorporate funds of knowledge into different classroom activities.

3.2 Funds of Knowledge Video Script

3.2.1 Script Introduction

[EXT, solo person talking, standing on concrete steps outside]

Funds of knowledge, defined as "collections of knowledge based in cultural practices a part of families' inner culture, work experience, and/or daily routine" (González, Moll, and Amanti, 2009) and "bodies of knowledge/skills working class families possess to survive and make a living" (Smith & Lucena, 2016) are a new concept in engineering education that emphasize the value of pre-collegiate experiences that students who don't fit the stereotypical engineering demographic can utilize as a tool for understanding and navigating the engineering curriculum and profession. As an asset-based approach to engaging students, the funds of knowledge framework can broaden the entry to engineering, empowering students to leverage their work and home experiences to support their engineering education. According to research, this reinforces their decision to pursue engineering. In a study that surveyed a diverse pool of engineering students, funds of knowledge such as perspective taking and tinkering proved to not only further minoritized student interest in engineering but also to promote their beliefs about their engineering competency and ability to perform well. Funds of knowledge draw attention to a wider array of engineering-relevant activities that position low-income, first generation, and minoritized students to be excellent engineers. In the following videos, you will witness how three students within engineering from minoritized demographics use their various funds of knowledge to understand different engineering concepts.

3.2.2 Fund of Knowledge Script: Tinkering Knowledge

[EXT, voice over, student walking outside with his backpack, sitting and opening his backpack]

Meet Leo, a student who worked at a warehouse prior to coming to college. During his experiences, he developed a fund of knowledge called *tinkering knowledge*, which represents an understanding of tools and building things. He learned a lot about forces as it pertains to different belts, pulleys, and other mechanical structures. In physics heavy engineering courses, such as statics and mechanics of materials, warehouse experience and other forms of *tinkering knowledge* can be useful for understanding engineering processes.

[INT, study cubicle, student studying and looking at a Statics textbook problem]

Student A- Hey! Ready for that statics homework?

Leo- Yep! I'm pulling it out right now! Did you get a chance to look at it?

[INT, Student A sits down and pulls out homework, taking a seat]

Student A- Yea, I looked at it. (sighs) Did you figure out all of the forces?

Leo- I think so! You want to compare our free body diagrams?

Student A- [slides free body diagram in the direction of Leo] Here's what I'm coming up with. At point A, we've got the horizontal force pushing against the platform along x [motions with hand]

and at point B, we've got the vertical upward force along y. Now the hinge for point C had me a little confused, but I'm pretty sure we've got forces along all three axes

Leo- I would argue that we've also got a vertical force at point A and I'd say that the horizontal force at point A is along the z

Student A- Hmmmm, interesting. Well, looking at the drawing, it looks like the pin is pushing against the platform along the x

Leo- Ok, story time (student puts down pencil and starts to smile). I used to work at a factory growing up and I would always see structures like this. I see what you mean...if the pin pushes against the platform at that point (indicates with pencil), then wouldn't there be a force acting at that point? But, when you see something like this in person, you'll see that there is literally no stress on that platform in the x direction. It's just sitting against it, but it's like...friction or something is keeping the platform from sliding along the y and z directions. Because it says the pin is removable and not fixed, we could say that it's not really being held in place because of the platform but more so the friction from the platform, I think

Student A- Ok...so point A would not have a force in the direction of the pin.... even though the platform is not moving here?

Leo- Right...because the platform and the pin are just sitting next to each other and its really friction acting along the y and z that keep the platform from moving

Student A- (laughs) it seems like its purpose is a little unnecessary...

Leo- Additional support to stop the platform from slipping and sliding. I feel like...if it pushed up against the platform, then that would really be a pointless force!

(both students laugh...scene fades)

3.2.3 Funds of Knowledge Script: Resourcefulness

[EXT, voice over, student getting out of her car with her backpack and walking towards college campus, pulling out her laptop and sitting down at a table]

Meet Cassie, who grew up where everyone worked multiple jobs and juggled one source of transportation. This caused her to understand the fund of knowledge called resourcefulness which helped her navigate multiple demanding priorities among limited means. ABET criteria emphasizes the importance of designing with specific needs that considers a multitude of different factors, from social to political to economic, and being able to design and prioritize various needs of a project considering those factors.

[INT, three students sitting around a table with their laptops and backpacks]

Cassie- So, for the water distribution system, I've been researching some of the least costly methods to filter and disinfect and figured we would want to build something with some filter cups, maybe cheesecloth...and I've seen some cheap options for purchasing mini UV rays

Student A- Yea, and maybe we look into purchasing life straws for the community

Cassie- I think we've got to go more basic...try to think about what they have readily available

Student A- It's a pretty rural community

Student B- Plus we are allowed to transport materials and hire help

Cassie- But I think we want something that uses materials already available that's easy to assemble so we don't need to spend a ton of time on training or budgeting for some expert salary...I think we use what we have and make something work

Student A- What type of materials are you thinking of?

Student B- Because we'll want the water to meet certain standards too

Cassie- When I was researching the typical contaminants in the water, I was seeing a lot of suspended solids as well as bacteria and such, so I'm thinking we use some of the natural landscape in our filter system like looking at what plants are in the area, soils, rocks, clay, sand, that type of thing…

Student A- What about aesthetics?

Cassie- After the water filters through our media, it sits in a glass jar that gets boiled…that's where it gets disinfected, then-

Student A- (cuts in) I just think we may be simplifying our solution a bit much

Cassie- I think we start from basics, and as necessary, add more money/resources/human capital...I don't think it's best to approach the project assuming we'll have access to certain things that actually may require more money, time, and planning than we thought about

Student B- I see…

Cassie- And we can still test our water here to make sure we meet necessary standards...maybe network around and see how we may obtain a water sample from the community

Student B- Yea, good idea

Student A- I just don't want us to short change the community with something too simplified

Cassie- To offer a different perspective, when I was growing up and didn't have much money, transportation, or even parents around half the time...it just kind of forced me to think outside the box and on my toes

Student B- Well, we definitely need that type of thinking right now...

(end scene)

3.2.4 Script Conclusion

[EXT, solo person talking, sitting on a rock outside]

Funds of knowledge have the potential to transform our understanding of who engineers are and what sorts of skills make them successful. When instructors and professionals in the industry embrace this concept, we can see students from all types of backgrounds use their home and work experiences to scaffold their engineering learning and to solidify their self-confidence. Instructors should directly encourage these connections through their teaching. Students can be invited to map their own funds of knowledge at the beginning of a semester or project and instructors can present a broad vision of engineering that encompasses them. Classroom activities could nurture opportunities for students to use the funds of knowledge they identify in their engineering learning, such as taking apart and rebuilding household items, designing for affordability, or learning from skilled tradespeople. Research also suggests that first generation students carry unique knowledge about managing interpersonal relationships, such as mediation and perspective taking, which is essential to teamwork and successful engineering projects. Incorporating funds of knowledge can better equip students for engineering careers in which they need to design for diverse pools of stakeholders. This is the engineering future we can aim for! My name is Arielle Rainey, and thank you for letting me share my participation in researching the importance of funds of knowledge for engineering education.

3.3 Future Script for Fund of Knowledge: Empathy

[INT, student walking a building hall]

Meet Student A, who grew up very close to multiple family members and developed a fund of knowledge called empathy, giving her the capacity to understand what others may be feeling. She witnessed an elderly family member struggle with medical challenges and a young niece born with a disability. These experiences demonstrated to Student B how necessary empathy is within the design process so that students can better relate to marginalized and victimized stakeholders.

[INT, three students in a classroom with their desks pushed together, looking at a laptop screen]

Student 1- So, we were discussing our design solution last night and think that the best route to go with a water supply for the community is to install a hand pump well

Student 2- Yea, it just makes the most sense...I mean, looking at a lot of these types of projects, wells have been so successful because they can be easy to install, low maintenance and oversight, feasible…

Student 1- Yea...it's the best option

Student A- Well, I've been working on the stakeholder section, and we need to consider that a large part of the population has a disability

Student 1- Really? (looks at Student 2)

Student 2- (looks back at Student 1 perplexed) I don't think we needed it to be that focused, I mean, most of the time, we are analyzing stakeholders in terms of the people in the community who are in charge of the materials, who will pay, who will train the people on how to use it, and training can accommodate for things like that

Student A- Yea, but what if it doesn't? Won't people in power have more autonomy to exclude others from access to clean water?

Student 2- Well, the government will probably regulate things like that

Student A- I just don't think we can assume proper dissemination of resources and all of that...I think we really need to design to try to accommodate who the community actually is instead of rely on whoever is in charge in the community to be inclusive to everyone

Student 1- So, are you saying we need to get statistics on everything about the people who live there? What other types of things do you want to look into?

Student A- I'm mostly trying to consider all the ways people can be marginalized

Student 2- We looked at income

Student A- Yea, but disadvantages can exist everywhere. In my family, we've got people with physical disabilities, mental disabilities, you just got to think of all the challenges people can face

Student 2- It's just tough to know all of that and try to figure it out on our time limit

Student A- Yea, but we've really got to prioritize it...stakeholders are the heart of the project, and the ones who are the most marginalized are the most important stakeholders, I think

Student 1- That's a noble perspective

Student A- (laughs) Let's just say I've got a lot of people close to me who I hate to see go through life unconsidered when it comes to how things are designed

Student 2- (smiles) Totally understand...let's try to brainstorm a more disabled-focus water supply

(the three students all nod as scene fades)

3.4 Funds of Knowledge Mapping Activity

This activity can demonstrate a technique to help students connect different meaningful activities and habits from their childhood and daily lives to their engineering interest. The activity is a tool to help students understand the assets in their own individual backgrounds that can scaffold their engineering education, especially in ways that emphasize skills that are often not learned in the classroom.

3.4.1 Childhood and Daily Activities

In this section, students think of various activities from their childhood and current daily lives that are most meaningful or impactful for them. These activities can consist of work-related tasks, personal hobbies, and anything pertaining to family or community life. The main qualifier for these activities is that they are influential for the student's life in a way that the student has a significant amount of knowledge accumulated in this area. Often times, students can include events and traditions unique to their cultures. For my childhood and daily activities that hold a lot of meaning and value to me, I would select the following three depicted in Figure 3.2 below.

Figure 3.2 Arielle's meaningful childhood and current activities

These are activities that I have performed on a regular basis on multiple occasions and therefore are a large part of my personal and daily life. The activities hold value to me because of how embedded in my daily routine they are or were at a time.

3.4.2 Current Engineering Interests

In this next section, students reflect on what current themes, activities, or concepts related to engineering cultivate the most engineering interests and are possible directions students would like to take as future career choices. My personal current engineering interests are outlined below in Figure 3.3.

Figure 3.3 Arielle's top engineering interests

3.4.3 Connecting Activities to Engineering Interests via Funds of Knowledge

In the last section of the mapping activity, students will insert various funds of knowledge accumulated throughout their personal lives from their childhood and daily activities and relate these funds to how they can be successful in their engineering interests. I illustrate these connections below in Figure 3.4 by connecting the activities detailed in Figure 3.2 with the interests from Figure 3.3. The connections described detail how I turn my personal activities into funds of knowledge by demonstrating how the activities develop different skills and types of knowledge that are useful for understanding the interests I outline. By establishing these connections, students can exchange their funds of knowledge into useful tools that scaffold their engineering learning. For example, connecting my involvement in many outdoor activities to my interests in engineering field work allows me to give meaning to that engineering interests by tracing how I came to acquire knowledge that allows me to be successful in performing engineering field work. Funds of knowledge can be transferrable to all types of students, not just first-generation students, and they can apply to more than just engineering. Therefore, there is a universality to funds of knowledge that showcase how educators everywhere can connect students' personal lives to what they learn in the classroom, therefore making these activities more meaningful and personal.

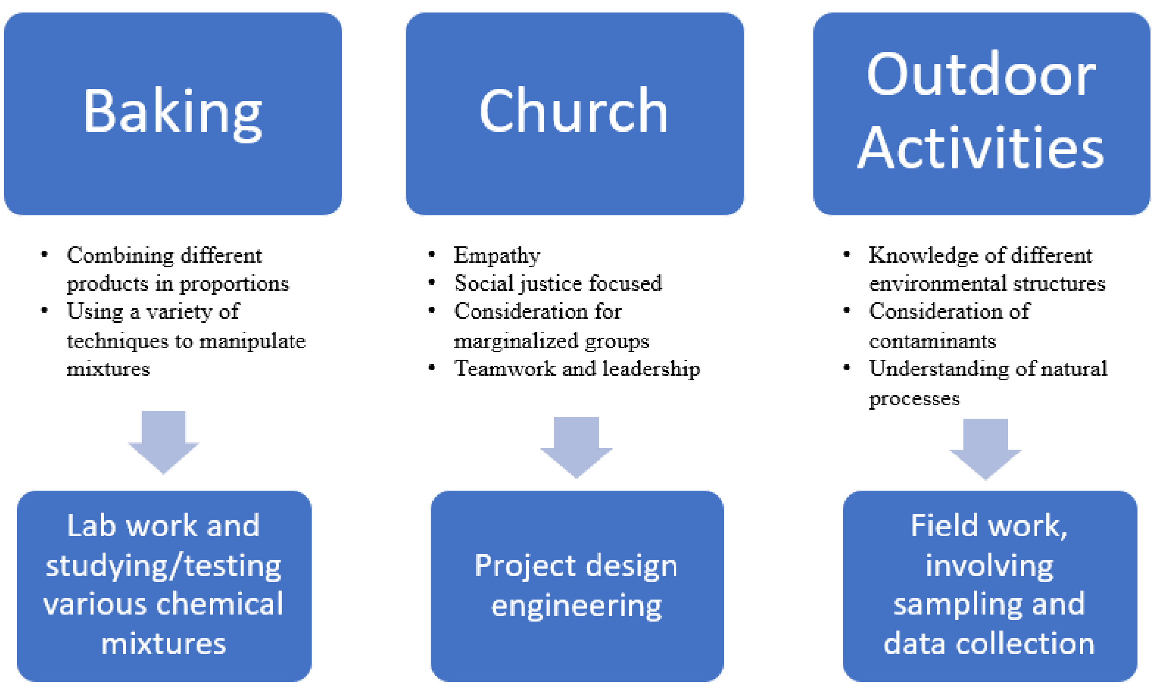

Figure 3.4 Arielle's connection of activities to interest to promote funds of knowledge

3.5 Supplemental Project Questions Based on Funds of Knowledge

3.5.1 Resourcefulness

To activate the fund of knowledge of resourcefulness, the scenarios below are designed to help students use the knowledge of resourcefulness towards an engineering project and emphasize how resourcefulness can be a useful tool for being a successful engineer.

1. Water Resources Project: While students may use their technical knowledge towards designing a device for water resources or to calculate different values, questions to activate resourcefulness can focus on assigning prices to different device parts and causing students to include a financial aspect to how they design solutions. Students can also be allowed a limited set of resources to include in the project and must assign value to what resources they would spend money on vs. what areas of the project they can rely on free or personal resources. For instance, perhaps the student must choose between buying materials to construct a weir, or they could choose from a pool of recycled materials. In the pool, the project could include different needed materials so students must choose between what types of materials they would want to buy new or use a special type vs. the materials they could save money and time by choosing from the recycled pool.
2. Energy Project: With a focus on creating sustainable designs, another project could have students choose a specific area where they will implement an energy grid, but they must only use options from the local community. This would cause students to make use of their surroundings as opposed to reaching for outside support to meet local needs while also causing students to brainstorm and innovate creative ways to address a problem when they have limited means. There would also be a research element involved because students would need to learn about the area and look into current energy methods.
3. Disaster Mitigation Project: Students are tasked with designing a solution to mitigate a natural disaster or hazard that has affected a specific area. This project can include a time element, so students learn to make use of limited time, by giving students the option to access selected personnel from a pool of individuals involved in city planning, management, disaster response, and any other individuals beneficial for disaster mitigation. From this collection of data, students will create a proposal to effectively mitigate the disaster threat. By causing students to choose which opinions and information they can include from among a variety of people, students can apply resourcefulness in a new way

by deciding how they will conduct their time depending on which personnel can provide the most beneficial information. The project could also include a set of different activities to conduct with the personnel that will have an assigned time element while the students must organize these activities with a time constraint. For instance, perhaps students could include interviews for a flood mitigation project of homeowners and businesses in the flood zone that would take a total of 20 hours to complete, then they could attend a workshop with city officials that details previous mitigation efforts and their results that would take 5 hours to complete, all the while the students have an allotted time of 50 hours to compile data from personnel for their project.

3.5.2 Empathy

Empathy, another fund of knowledge based on interpersonal skills, could be a focus for supplemental questions by causing students to consider the human element of their designs in a way that puts the user first and considers the marginalized, the poor, the disabled, and many other people groups that engineering can often overlook.

1. Lab Based Activity on Environmental Contaminants: This project focuses on how even a lab activity can have an element of empathy involved. Students are tasked with cleaning up a community that suffers from environmental contamination in a multitude of areas from both water, soil, and air. They are given various metrics on environmental pollution in the community as well as demographic information for the community and risks information so they understand the effects of the environmental contamination. They are given different clean-up activities they can implement all under the constraint of a budget. The lab portion would include the students given limited samples they can run from the community, allowing them to choose which locations they will gather samples in order to determine which areas to focus on and to see just how badly the contamination affects the areas. The project will foster empathy by including a write-up associated with each clean-up activity they choose and why. A possible scenario could include a prison in the community, and perhaps the students choose a clean-up activity directly affecting a prison vs. a local mall because they understand that prisoners will be at the prison 24 hours a day vs. people occasionally at a mall which would cause prisoners to have 24-hour exposure to

contamination. This type of thinking requires empathy because it realizes the disadvantage certain people in a community may have in comparison to others.

2. Civil Based Activity on Bridge Construction: Another empathy fostering challenge can have students involved in choosing a site for bridge construction as a portion of their project. The project will have a fictional description of the community and the different areas included, what they are populated with, and other general demographic information. A write-up portion would accompany the project to ensure students describe why they choose the site they do and how it will impact stakeholders. Students will be pushed to think in terms of the community and weighing options for their location based on who benefits and who doesn't. The challenge will be trying to find a location that emphasizes the greater good for the most individuals, or the greater good for the most marginalized, or whichever stakeholders on who the student chooses to base the decision. The activity will enforce students to think in terms of how they might mitigate competing priorities and how empathy may influence their thinking by which stakeholders they choose to include in their decision process.

3.6 Conclusion

This practical application for funds of knowledge could be a fun and unique way to start translating the collection of research to educators and students so funds of knowledge can be more than just a theoretical concept, but a useful tool included in the engineering classroom. The activities included are suggestions on how the classroom can start incorporating funds of knowledge in a way that scaffolds learning and develops necessary skills that help students become successful engineers, especially in a sociotechnical space. The type of engineering these funds promote follow the humanitarian approach because of the emphasis on interpersonal skills instead of just technical knowledge. This approach also complements the vast amount of curriculum that is currently being pushed for culturally relevant pedagogy, where educators are attempting to transform teaching in a way that reaches diverse populations of students. Funds of knowledge are universal and versatile enough to where many types of students can and will benefit.

CHAPTER 4

HOW AN IMMERSIVE, FIELD-BASED, SOCIOTECHNICAL SUMMER SESSION INFLUENCES UNDERGRADUATE STUDENT PARTICIPANTS' SENSE OF BELONGING IN ENGINEERING

4.1 Introduction

Engineering has taken on many types of focuses throughout the decades. In the late 18th to early 19th centuries, as new nations began to emerge, engineers would work alongside the engineers from these new nations to build national infrastructure and develop the new nation's natural resources. These engineers were not very focused on community development or environmental sustainability as much as they were simply building a new nation. During the late 19th and early 20th centuries, positivism became a dominant thought process within engineering (Lucena, Schneider & Leydens, 2010). Positivism involves two mindsets: reductionism, which believes that big problems are capable of being broken into smaller components to analyze separately and explain the entire system, and technological determinism, which sees technology as independently impacting all facets of life, from social to political to economic (Riley, 2005). This perspective causes engineers to see many things as objective and therefore see science as neutral, ignoring any ways that social and political factors may influence the way science is understood. As engineering drifted into the first half of the 20th century, engineers became more nationally focused and projects that were capitalistically driven and corporately run were the dominant type of engineering work. Engineering work that involved development in other countries was focused on development that spurred the interest of the home countries' needs. After World War II, international engineering became more popular as engineers from modernized nations sought to modernize developing countries, thinking they would bring technology and development to countries that still practiced traditional infrastructure and technology methods. This influenced the idea of technocracies, which are defined as societies where technical experts take charge of nationwide planning and organizing, approaching social problems with technical solutions and using technology to control and manage people. During the Cold War, many of these international projects were inspired by the idea of halting the expansion of communism and growing capitalism, still neglecting environmental sustainability and human populations (Lucena, Schneider & Leydens, 2010).

Engineering did take a turn in the late 1960s and early 1970s when engineers started to consider how their international projects fit into local contexts, and more focus began to shift towards developing inexpensive technologies to transfer to developing nations. One particular group called Volunteers in Technical Assistance from Rensselaer Polytechnic Institute believed that technology transfer could help develop technical knowledge in the local context, initiating the connection between volunteerism and technology. However, even with this shift towards considering local populations, the mindset towards these nations was still one of the engineers as superior and the locals as inferior. Knowledge was only transferred to the developing nations as opposed to the mutual exchange of knowledge; environmental sustainability was still an afterthought and community values were excluded from the engineering process. Because of the heavy influence and reliance on ABET criteria, engineering still focused on mostly math and science driven solutions (Lucena, Schneider & Leydens, 2010).

In the 1970s, there was a rise in the questioning of technology and its heavy usage when solving domestic problems. The United Nations shifted the approach in international development towards more humanitarian goals, such as eliminating poverty and social justice. However, still problematic in this approach was the goal of raising the living standards of the people considered the lowest in society so that they could eventually merge into the international economic system. These nations were still seen as incapable of taking charge of their own solutions for domestic concerns, and international development still seemed to pinpoint what it considered to be the problem for these nations and thus what the best solutions would be. Communities were viewed in terms of what they lacked, not the richness within their own cultures and societies. This “basic needs” approach to international development dominated popular thinking well into the 1990s (Lucena, Schneider & Leydens, 2010). The 1980s saw the shift away from centralized engineering projects and more geared towards privatization and industry focused development. This caused international engineering to be less government reliant, but still enforcing the same power dynamics that it always had in terms of the local communities.

Recent international development has started to incorporate more green ideology as developing engineers start to focus on sustainability and impacts of development. This shift has not been widely embraced across the spectrum of engineering, as some still see the risks in considering sustainability to outweigh the potential for economic competitiveness. Government initiatives are forced to incentivize this focus on green development to encourage the shift in priorities. As engineering has progressed into the 21st century, ABET criteria now reflect this rising need to consider environmental impacts of development and sustainability. But even with this new focus in international engineering, students are not prepared to meet sustainable development challenges, social justice issues, and gather and incorporate stakeholder feedback. Most engineering institutions do not reflect a desired knowledge outcome for design engineering of these components within their curriculum. Even with the emergence of community focused engineering groups such as Engineers Without Borders, Engineers for a Sustainable World, etc., a challenge still exists with merging the focuses of these types of organizations with the knowledge produced in traditional engineering education.

Following the emergence of humanitarian engineering, an industry disconnect is starting to form for engineers who desire to pursue community development. As criteria becomes popularized for international development projects, many current organizations in this space even fail to address all the components that criteria stress as pertinent for a successful international project. Bridger & Luloff (2005) developed a criterion that considers spurring economic autonomy, protecting biodiversity and natural resources, and encouraging social justice within local communities as focuses for international development. Just recently, Smith & Lucena (2020) further expanded international development to not only consider the project outcome criteria but also the processes involved in the design engineering space. They advise engineers to consider eliminating power structures that keep certain groups in power as the keepers and disseminators of information only, to seek out knowledge and needs even from the most marginalized within the local community, and to examine ways to collaboratively assess outcomes from projects to make sure there is a continued relationship between engineer and community that involves both parties making sure development projects don’t just end successful but remain successful.

This study focuses on a group of engineering students with a desire to enter the humanitarian engineering space for international development. While all students come from traditional engineering majors, ranging from civil to mechanical to environmental, these students share a passion for ultimately pursuing careers that are focused on projects within developing communities. This paper explores how these students reconcile their career outcomes with their current learning by exploring how a program designed to bridge the gap between traditional engineering knowledge and the desired design process for community development influences these students belonging to the engineering industry, their major, their academic faculty/staff/peers, and their respective institutions.

4.2 Theoretical Concepts

4.2.1 Engineering Mindsets

As engineering progressed from its onset in the 18th century to what it has become today in the 21st century, certain mindsets have prevailed through the centuries as a part of engineering culture. As mentioned in the introduction, positivism is a dominant thought process within engineering as students take positions of objectivity, focusing on technical knowledge, breaking large problems into smaller components with a technical solution applied. Meritocracy and depoliticization are also themes prevalent within engineering. Meritocracy believes that life outcomes are the result of individual talent and effort. Embedded within the "American Dream", this mindset believes that "you get out what you put in", ignoring inequalities, instead focusing on equal distribution of resources as a starting point for everyone. Depoliticization sees technical knowledge as a separate domain from social and political factors, thus capitalizing on positivism, focusing on the scientific method as an appropriate approach for all engineering problems (Cech, 2013). These mindsets can be deeply problematic for engineers involved in development who need to be aware of social justice, power structures, and marginalized groups. For engineers who must consider these factors within their design process, it can cause them to ignore context and see all individuals within a society as the same, not considering that some groups may be neglected or even refrained from having a voice in society. These mindsets also cause engineers to disregard the historical social and cultural impacts that exist within a society from past colonization and development and how these histories impact where the society stands today. Engineering education does not typically account for how these mindsets can skew design processes because it does not look at engineering problems through a social, political, or cultural lens. For students desiring a career in international development, these dominant mindsets can contradict the very nature of social justice and how designing with that framework must consider societies as unequal playing fields and as an integration of various social, political, economic, cultural, and technological structures all influencing one another. Thus, students are ill prepared for how to account for these components when designing for communities.

Another mindset that traditional engineering education progresses is the reliance on technical expertise. As the engineering curriculum expanded to include rigorous math and science-based courses, engineers have been regarded as knowledge experts, especially in the development space. This hurts engineering students in the international development realm because they have a hard time integrating other forms of knowledge with their heavy math and science background and trying to weigh how to best incorporate local knowledge with technical expertise. Though ABET criteria has included focuses on nontechnical skills such as professionalism, teamwork, and communication, these skills are not taught with the same persistence (Riley, 2005). Very dominant within engineering culture is the status and rigor that curriculum seeks to embed within students and remain a factor for engineering professionals, which further initiates the mindset of technical expertise as superior knowledge. A status and rigor focus encourage engineers to pursue careers attached to large corporations with global presences, typically involving military and corporate driven projects, and also to develop a strong, rigorous, technical background that includes math and science skills beyond what engineers may even encounter in their fields. However, what rigor can neglect is a space for innovation, creativity, flexibility, and imagination. Rigor causes engineers to focus on a systematic process involved in engineering instead of thinking outside the box for new and atypical solutions (Riley, 2017). There are some who see rigor as a way to weed out students from engineering and keep engineering as a system that perpetuates certain types of knowledge, which is typically knowledge embedded in western culture. This can neglect knowledge that is valuable for cultures outside of western society, which puts students outside of the dominant culture at a disadvantage. When considering international development, a rigorous background can cause students to subconsciously elevate knowledge from western culture as superior to local knowledge because they tend to view engineering problems from this context, mainly as a result of the education to which they've been exposed. Since engineering teaches the reliance on a single right answer as a standard for many engineering problems, students aren't encouraged to consider new possibilities and curiosities. Riley (2017) further argues that rigor is meant to incorporate discipline, developing a tolerance for heavy math and science intense courses that may lead to long nights of studying, demanding course loads, and mentally taxing exams so that students are well equipped for status focused careers where projects are more likely to rely on this type of knowledge predominantly.

4.2.2 Belongingness

When engineering students do not identify with the dominant mindsets perpetuated within engineering, their belongingness to engineering can be jeopardized. Belongingness has been defined two different ways in research. One definition presents belongingness as "a student's sense of belonging within an engineering context...defined by an individual's self-measure of 'fit' within a higher education institution's social and academic systems" (Hoffman, Richmond, Morrow & Salomone, 2002). In the second definition, belongingness is seen as "a student's perceived social support on campus, a feeling or sensation of connectedness, the experiences of mattering or feeling cared about…" (Baumeister & Leary, 1995). This paper considers belongingness from both perspectives but predominantly as a measure of fit, seeking to understand how well individuals feel that they fit into their environment as opposed to exploring their emotional connection to their environment.

Belongingness can also be explored in a variety of contexts: a student's major, their classroom environment, their institution, their overall profession, their peers, and their faculty/staff. This paper focuses on belongingness from all of these contexts. Dominant literature that explores belongingness typically focuses on specific demographics to understand that population's belongingness within the different contexts. One finding pertains to gender and how female students in the classroom can feel a lack of belongingness coming specifically from male peers. This is pinpointing a lack of belongingness in a classroom targeted from male peers, which research shows from students' testimonials where female students cite they feel exclusion from their male peers or like they are type casted for certain roles, such as being a notetaker (Kirn, Godwin, Benson, Potvin, Doyle, Boone & Verdín, 2016). Another study focusing on black students within predominantly white institutions found a lack of belongingness for the black students towards their institutions, much of which stemmed from experiences from faculty and peers. So, while the students did feel a lack of belongingness overall to their institutions, it resulted not necessarily from the structure of the engineering institution, but from the treatment they received from faculty and peers. Students talked about feeling like they had to be on the defensive and being treated like they didn't know what they were talking about (Berhan, Kumar, Goodloe, Jones & Adams, 2018).

Belongingness can also be higher for one domain and lacking in another, so while students might feel connected to their peers and faculty, they may not feel belongingness towards engineering as a major or profession. And students who may feel belongingness to engineering as a major and profession may cite examples of lacking belongingness to those around them. While this has not been heavily explored in belongingness literature thus far, this study demonstrates some instances of this experience for students who feel more belongingness from one realm of their engineering experience vs. a significant lack of belongingness from another realm. The reasons for this are worth exploring, as a lot of it may stem from mismatches in how students want to engineer and the types of engineering to which they are exposed. As new majors within engineering become more popularized at predominant engineering institutions, students may find a niche where they previously hadn't. Lack of belongingness usually stems from a lack of understanding from the dominant culture as to who should be engineers and what engineers should do, and much of this has been perpetuated by the popular narrative of engineering, rooted in mindsets that downplay the significance of knowledge outside of the positivist, rigorous, and status filled culture that engineering embodies.

4.3 Methods

4.3.1 Research Question

This study explores the effect an immersive, field-based, sociotechnical engineering summer program has on engineering students enrolled in traditional majors with regards to how they feel belongingness from their institutions, majors, peers, classroom, faculty, and the overall profession of engineering.

How does an immersive, field based sociotechnical field session influence undergraduate students' belongingness in engineering?

The research question was evaluated via semi-structured interviews occurring prior to the field session (detailed in Appendix B) and after the field session (detailed in Appendix C). The interviews prior to the field session lasted approximately 30-40 minutes while the interviews conducted afterward lasted 20-30 minutes. Additionally, students completed a survey prior to and post the field session that used a Likert scale that measured their sense of belongingness in the different contexts (detailed in Appendix D). The items used to measure belongingness were very similar to previous indices used in engineering literature. Leibowitz et. al (2020) developed a survey that measured sense of belongingness for STEM students focusing on constructs such as self-efficacy and academic engagement and specifying belongingness in certain contexts: sense of belongingness to the institution, academic major, and residential community. This study follows a similar approach but qualitatively analyzes the resulting data. Future work can explore more quantitative procedures to measure sense of belongingness in the same fashion as Leibowitz et. al (2020), instituting more control measures to account for any changes in belongingness that generally occur and may not be due to the field session.

4.3.2 Participant Demographics

In Table 4.1 below, descriptor information for each undergraduate is shown; eight students were interviewed prior to the field session and seven students were interviewed afterward, one student declining a post interview.

Table 4.1 Undergraduate Summer Program Participant Demographics

Student Acronym	Major	Home Institution
BK	Civil Engineering	Air Force Academy
AB	Civil Engineering	University of Texas
AN	Civil Engineering	University of Texas
EH	Chemical Engineering	Colorado School of Mines
ER	BSE- Energy Studies	Colorado School of Mines
GQO	Geological Engineering	Colorado School of Mines
NG	Geological Engineering	Colorado School of Mines
ABG	Chemical Engineering	Colorado School of Mines

4.3.3 Data Analysis

Interview data was analyzed using an inductive approach because themes affecting a students' sense of belongingness were drawn from reviewing interview data, and those themes were then coded as either a way to increase a sense of belongingness or decrease a sense of belongingness. Finally, the themes were characterized by realms to figure out to where the sense of belongingness pertained, either to the classroom, the major, peers, faculty, etc. The survey data was interpreted numerically via a table pre and post session that detailed the students' overall sense of belongingness with a focus on sense of belongingness for each of the different realms. This data analysis utilizes a qualitative approach by choosing to focus on major themes for analysis and deriving conclusions. The approach is meant to summarize the major findings, according to themes, from the raw interview data and survey results for the purpose of drawing conclusions that are evident from the data (Thomas, 2006). Whereas the interview questions detail a specific student's sense of belongingness, how it changes, and to what it pertains, the survey data classifies the students as a collective to make more general conclusions about how an immersive, field-based, sociotechnical summer session affected the students' sense of belongingness as a whole.

4.3.4 Limitations

While eight students were interviewed out of the field session, there were more students apart of the program. Therefore, the opinions and statements reflected in the data are from the perspectives of a portion of the participants and thus may not provide a comprehensive summary of how all the students were impacted.

4.4 Results

In Tables 4.2 through 4.5 below, the themes identified throughout the student interviews are displayed, grouped by the themes that foster a sense of belongingness pre-field session (Table 4.2 p. 54) and post field session (Table 4.4 p. 55), as well as themes that hinder a sense of belongingness pre-field session (Table 4.3 p. 56) and post field session (Table 4.6 p. 57). The tables also differentiate to what type of belongingness the themes apply: major, profession, institution (which includes academic staff, programming, and other features of the university), classroom, faculty, and peers. Themes in bold text represent themes that were expressed during both the pre and post field session in order to demonstrate the consistency of some themes. The number of times each theme appeared was not included, but some themes were reflected in multiple student interviews whereas some themes were discussed by one student in their interview. The depiction of these themes presents a narrative of the contexts to which belongingness is most frequently referenced pre vs. post field session.

Table 4.2 Themes Correlating with a Sense of Belongingness Pre-Field Session

Themes Identified	Major	Profession	Institution	Classroom	Faculty	Peers
Encouraging faculty who offer guidance with internships/programs and who care about helping students pick classes and navigate career choices			**X**		**X**	
Faculty that challenge students, are approachable, open-minded, nonjudgmental and help students achieve					X	
Forming connections that benefit students post college					X	X
A workload that prepares students for engineering in the future; success through hard work and perseverance; mastery of technical concepts				X		
Engineering that helps others, has an obvious purpose, and is sociotechnical in nature		**X**				
Faculty who are passionate and engaged about what they teach and are good at teaching to where students can understand					X	
Collaborative atmosphere				X		
Opportunities for research and further in-depth exploration of topics			X			
The feeling of freedom and choice when it comes to different career paths one can pursue in their major	X					
Appreciation for experiential learning & direct application of concepts				**X**		

Table 4.3 Themes Correlating with a Lack of Belongingness Pre-Field Session

Themes Identified	Major	Profession	Institution	Classroom	Faculty	Peers
Faculty who seem to not care whether their students learn; faculty who just want to pass students, no personal engagement					X	
Getting directed to take the wrong classes			X			
Faculty who don't explain problems and just use PowerPoint slides and reference materials for students who need help to copy; focus on memorization					X	
A workload/rigor that causes students to academically struggle and question their ability to engineer				**X**		
Focus on lucrative careers vs. fulfilling careers			X		X	X
Faculty who lack personal engagement with students					X	
Faculty who assume students should have more technical knowledge than they do, making them feel dumb asking for help					X	
Not relating to peers in regards to engineering interest						X
Competitive/exclusionary culture						X
Faculty who can't direct students in the direction of their interests and only have information regarding things they personally have experience with					X	
Lack of understanding towards mental health challenges					X	
Barriers for international students		X				

Table 4.4 Themes Correlating with a Sense of Belongingness Post Field Session

Themes Identified	Major	Profession	Institution	Classroom	Faculty	Peers
Appreciation for experiential learning & direct application of concepts				**X**		
Finding new solutions as opposed to using existing ones				X		
Engineering that helps others		**X**				
Receiving direction and witnessing pathways that correlate with engineering interests			**X**		**X**	
Seeing how the technical and humanitarian nature of engineering can work together		**X**				
Fluctuation in design; an iterative process that incorporates community feedback and information exchange	X					
Successfully finishing a project that includes technical and social needs				X		
Diversity in collaboration and teamwork when designing a solution		X				X
Seeing connections between conceptual learning and experiential learning				X		
Finding others who share the same passions in engineering						X
Engineering that makes students feel engaged and excited				X		
Feeling valued as a person by faculty and older students (grad students) as opposed to being treated like a child					X	X

Table 4.5 Themes Correlating with a Lack of Belongingness Post Field Session

Themes Identified	Major	Profession	Institution	Classroom	Faculty	Peers
Feeling inadequately prepared to engineer for communities, both from lacking technical information pertinent to what a design solution may need and social knowledge to address community concerns	X					
Feeling unable to see the connections between conceptual learning and direct applications				X		
Peers focusing too much on the technical aspects of the project						X
A workload and rigor that causes students to academically struggle and question their ability to engineer				**X**		
Not being able to be involved in implementation steps because of project duration				X		

Table 4.6 on p. 58 displays the results of the survey data pre and post summer program. Students answered a total of 25 questions for each survey, before and after, using the Likert scale (1-5) to rate their level of agreeability with the statements. Higher values represent more agreeableness to the statements whereas lower values represent disagreeableness. To get a composite score for all of the statements, the students answers were totaled to see overall how the group of students would describe their belongingness for the different realms pre and post the summer program. The different realms of belongingness displayed match the realms discussed in the interviews. The question(s) that pertained to each realm were extracted so that belongingness could be compared for certain topics specifically. This is a qualitative assessment of the survey data because scores were cumulatively totaled for comparison factors, analyzing general trends of how sense of belongingness changed for the students' overall. Appendix E details a table that

depicts how each individual student's sense of belongingness changed from pre to post field session for each of the questions on the survey related to a belongingness context, including the cumulative scores that demonstrate how the totals in Table 4.6 were generated. Because the surveys were anonymous, the belongingness scores weren't analyzed for demographic trends, just understanding the overall trend of belongingness scores for the different contexts pre and post field session. The analysis of the data was cumulative and qualitative in nature.

Table 4.6 Survey Results for Student Group Pre and Post Field Session

Belongingness Type	**Pre**	**Post**
Classroom		
I feel welcomed by my classmates in engineering	27	26
Peers		
I feel welcomed by my peers in engineering	28	23
Faculty		
I feel welcomed by my engineering professors	28	26
Major		
I feel sure about my choice of engineering as a major	28	24
Profession		
I feel committed to engineering	31	28
Institution		
I feel that I am a part of my university	27	26
I feel supported by my university	27	24
I feel comfortable in my university	30	25
Overall		
I feel I belong in engineering	29	23

4.4.1 What Do Students Value Within Their Engineering Experience?

Based on the themes that were most prevalent pre and post field session, the data demonstrated what students' have and continue to value within their engineering education. Students talked about how they appreciated the merging of the social and technical nature of engineering. When asked about the top three characteristics of a program that solidify belongingness in engineering, EH commented "definitely some type of interdisciplinary approach to STEM". GQO also talked about desiring this connection as she reflected on how PIRE made her feel belongingness in engineering. She stated that:

> "because there are two different things you kind of like want to go for engineering because you're studying engineering, but then you also want to do the social part. But it's just like, how do I find a connection? So the only way I thought it was like, OK, like it's either engineering or social aspect, but like during the project, I realized that we work a lot on connecting both and how they complement each other, and both are as important or really important to actually find like good results."

Their interest in the social nature of engineering also aligned with wanting to incorporate community feedback, as students believed that understanding the social side of engineering meant community engagement. This was reflected as students talked about their excitement to witness engineering that helped people and engineering in which they could see the ultimate purpose. NG talked about feeling belongingness in an engineering program that was "human-centered…because engineering always applies to people". After the PIRE experience, NG further expressed her aspiration for engineering that has a social element involving the communities affected.

> "I really want to work with communities or at least in whatever I'm doing be aware that if we're working with communities or in a community that it's important to engage them. And that's what I really liked about the project is that we got to engage the actual communities and miners and ask them questions and ask for feedback, which I thought was really exciting and I really enjoyed it."

Additionally, students liked engineering that focused on applying conceptual knowledge through direct application in order to provide context to classroom learning. This allowed students to see the connections between concepts they would learn, and how those concepts would be applied in a real-world scenario. EH talked about the benefit of learning that is hands-on and engaging and how some of the activities she witnessed in PIRE were her first live exposure to abstract knowledge she has learned in class. Another important component of what fostered belongingness in engineering for the students was the direction and exposure they received which points them in a direction relevant to their engineering interests. For many students, faculty who can't offer them guidance in alignment with their engineering interests or who provide too narrow of a career outlook for their major cause them to feel a lack of belongingness because students can't make the connection between how their learning will direct them to a career they are passionate about. While one student reflected that it is important to know how to look for the programs and opportunities that can expose one to the type of engineering they want to do for the future, students generally shared the sentiment that engineering should be presented in a broad enough fashion to where students have ample options for the direction in which they would like to take their career. AN stated how a program that would solidify her belongingness in engineering would "give us a lot of opportunities for broad field projects, so you can just see what fits for you and what you're interested in, what you like to learn, and you can get really good at it."

One theme that caused a lack of belongingness pre and post field session was a workload and amount of academic rigor that caused students to struggle to the point where they questioned if engineering was the right career option. This theme demonstrated how students' belongingness was impacted by their personal level of being successful in their chosen field and how their belongingness was affected by how well they perceived they were doing. And when students academically performed well, they felt a greater sense of belongingness to engineering and felt accomplished because of their mastery of difficult course concepts. Their belongingness was correlated with how well they were doing academically.

4.4.2 The Influence of Faculty on Student's Sense of Belongingness Pre-Field Session

Prior to the field session, a majority of responses echoed a strong reliance on sense of belongingness as it pertained to faculty efforts. Majority of the themes students cited pre-field session as themes that either correlated with a sense of belongingness or lack of belongingness all resulted from their interactions with faculty. For themes that correlated with a sense of belongingness, students listed several characteristics that they appreciated within faculty: encouraging, offering guidance, challenging, approachable, open-minded, nonjudgmental, helpful, etc. AN discussed her faculty and commented "the faculty is very, they're very compassionate about what they do" and "I really appreciate that I can learn from them". Students then discussed traits of faculty that correlated with a lack of belongingness: faculty who don't personally care about students and just want to pass students, faculty with no personal engagement, faculty who don't explain problems and just direct students to reference materials, and faculty assuming students have more technical knowledge than they do. At the same institution, AB highlighted other experiences with faculty that have a more negative tone. He stated "like some of my professors, it seemed like there was more important stuff like passing a student and stuff than like teaching the material and making sure, like a student learns like if there was more focus on just like passing the class."

Research highlights the fact that faculty interaction plays a large role on sense of belongingness. Rainey, Verdin, and Smith (2021) pinpointed several ways in which faculty increase a student's sense of belongingness, such as by creating an environment of mutual respect and by providing personal feedback vs. handing out supplemental resources. These findings are in line with how the undergraduates in this study similarly want faculty to be more personally invested in their lives and want faculty to embody traits such as being encouraging and nonjudgmental, traits that foster an atmosphere of mutual respect. While the referenced study focused on ways to increase sense of belongingness for minoritized students, its similarities to what undergraduates from this study value within faculty prove the universality of these sentiments.

4.4.3 The Influence of the Classroom on Student's Sense of Belongingness Post Field Session

After the field session, student's reflections became more classroom focused as opposed to faculty focused, as was the case prior to the field session. Students discussed a lot of the elements present in the summer program that they appreciated and that made them realize they belong in engineering. NG expressed this moment as she talked about community engagement:

> "The moment that we got to interact with the community, I would say, would be like my top moment as far as an engineer because I don't think as engineers that we do that enough. And it was really exciting to see like, Oh, these people realize that we have some sort of technical knowledge that we can use maybe to better their processes, but we like attain that through social interactions or like we did an exchange of information. And I think that was really interesting and really fun, and that would have definitely solidified myself in engineering."

Similarly, the other undergraduates described their sense of belongingness in terms of classroom experiences, especially mentioning the direction and exposure they witnessed that allowed them to see a type of engineering more in line with what they envisioned for their future. EH commented how she felt after the experience stating "I'm like, oh, this is like, I want to take my life in this direction now. So it's kind of like giving me a new, better purpose, I guess." The important aspects of engineering that students appreciated prior to the program, such as hands-on experiences and real-world applications for conceptual knowledge, stood out to the students most drastically throughout the summer program. The program appeared to highlight those areas that students described as the traits of their classrooms and institutions that they liked.

However, all of their sentiments of the classroom did not reflect a sense of belongingness. Some of the students felt challenged by having to focus so much on social aspects, aspects they felt they lacked the adequate knowledge to address. While NG felt belongingness because of her ability to engage with communities, she also started to feel unfit to address the problems within the community with her limited technical, engineering knowledge:

> "It was difficult as engineers to maybe address the other underlying social issues in certain areas of Colombia, for instance, because we talked about a lot of things that we didn't talk about, like maybe the drug problems or like all of the underlying all of the other issues. And it kind of made me feel helpless as an engineer, maybe because it's like I just know math, like, what do I know about any of these social issues because I'm not from there. So maybe it made me feel a little bit less like I was an engineer."

Interestingly, while students seemed drawn by the sociotechnical nature of the program, it also proved to be a challenge and signifies the desire to address community problems yet feeling apprehensive due to how engineering education prepares students to tackle those challenges.

4.4.4 Sense of Belongingness Pre-Field Session vs. Post Field Session

In Table 4.6, the major differences displayed show that for all realms of belongingness and overall, student's sense of belongingness did decrease from the summer field session. Pre-field session, students appeared to have the lowest level of belongingness from the classroom and post field session, the lowest levels of belongingness were from engineering peers and the students' majors. Another interesting observation is how drastically sense of belongingness decreased for the engineering major, comfortability at the university, and belongingness overall. Additionally, pre and post field session, students demonstrated the highest level of belongingness to the engineering profession. Only one question portrayed in Table 4.6, the statement referring to peer belongingness, had a student who did not answer the question. It is unknown whether the student chose to abstain from answering this question or if they accidentally skipped the question. Therefore, the interpretation of the results relating to peers were assumed based on the general trend of the other responses the students gave. Survey results represent seven of the students from the field session and all were done anonymously. Though the survey questions highlighted only represent roughly a third of the questions asked, the other questions focused on students' desire to work in humanitarian, sociotechnical engineering spaces, not their sense of belongingness.

4.5 Discussion

The themes presented in this study shed light on the fact that students do desire a more sociotechnical, holistic, engineering experience that exposes them to more than just the technical aspects of a design solution. Students appreciate being able to engage communities, transfer knowledge, and incorporate values from the communities for which they engineer. This mindset signifies a new way of engineering, where engineers don't revere themselves as knowledge elites and instead realize the gaps that may exist when it comes to engineering for communities. Students expressed their own dissatisfaction with feeling as though they should have more technical knowledge to adequately design their solutions, and feeling as though they lacked the social knowledge to properly address other issues the community was facing. While students do not want to exist merely in a technical bubble where they can only handle aspects of a solution that require quantitative, numerical solutions, they also want to make sure they are prepared to design a holistic solution considering sociotechnical factors. This calls for engineering education to include within curriculum more knowledge on how students can design from a sociotechnical standpoint. Though engineers are not social scientists, it is beneficial for them to understand the social dimensions involved in their design solution because social factors impact technical factors, while technical factors impact social factors; neither exist as separate entities. Therefore, engineering needs to challenge students to consider how their users are personally affected by solutions. Aside from the criteria referenced in the introduction, students can always have an element of community engagement with any design project they are tasked with. Students should be able to identify the stakeholders in their projects, and projects should have an element of incorporating stakeholder feedback into design solutions. This feedback does not always need to surround quantitative analysis but can be targeted towards personal values, beliefs, and mindsets of the stakeholders affected. This would allow for a deeper understanding of the sociotechnical nature of the design solution.

Students also appreciate a chance to engage in hands-on, real world applications to scaffold the conceptual knowledge they learn in class. Students do not want to merely be exposed to different abstract principles, even early on in their engineering career. Many students commented on how their freshman and sophomore classes did not have many hands-on learning experiences and how the field session was their first taste of a problem applied in the real world. Students do not want to wait until later in their educational career to start seeing concepts applied. Because students appreciate being exposed to a broad curriculum that will provide direction for a variety of careers, it only makes sense to follow this approach and demonstrate a multitude of applications to which a student's major could apply. That way, students can witness early on how their major can be applied to a future career they desire. Additionally, students want a hands-on experience that requires them to use skills from several of their engineering classes as opposed to applications that only focus on concepts from one class. Just as engineers in the real world must rely on knowledge from many different classes, students would like to mirror this same reality in their education by exposure to more experiences that require cohesive, combined knowledge. This is typically something students encounter at the culmination of their educational experience, but students prefer more opportunities to practice this combined knowledge sooner.

Because the field session appeared to decrease student's sense of belongingness overall, though it included elements of engineering that students discussed they desire and appreciate, it is worth exploring how this mismatch is occurring for students. A few possible explanations are discussed: (1) Students may feel excited about the immersive, hands-on, sociotechnical program they were exposed to but inadequately prepared for this type of engineering from the experiences in their respective majors. This explanation correlates with one of statements the students made about lacking the knowledge to address their community needs. (2) Because belongingness was the highest pre and post field session for the profession of engineering and lower for aspects of engineering the students are exposed to within their universities, students may be embracing the sociotechnical, humanitarian engineering in which they participated but they don't feel this same culture exists among their majors, classrooms, peers, etc. (3) Lastly, the experience may have unfortunately caused students to question engineering. Collectively, they did mention some aspects of the program that they did not like, such as missing out on implementation and follow-up and some disconnect between conceptual knowledge they would learn in the lecture sections and the hands-on activities with their communities. This explanation could be addressed with revisions to the summer program, such as continuing with a part two more focused on aftermath community engagement and implementation and the lectures could be revised to solely address specific concepts the students use in their hands-on sessions.

Some other possible theories could be involved in the decrease of the students' sense of belongingness post field session. While students did negatively comment on certain elements pertaining to the content of the field session, they also commented on the overall logistics of the field session. Students described the brutal short time frame that included a large amount of work in general. This could have also impacted their responses in the interviews and surveys post field session. Another theory that should be considered is Cech's (2014) culture of disengagement that engineers may experience in their education. Cech performed a study of students at four colleges and tracked multiple factors, one of which pertained to how their public welfare beliefs changed during their education. She concluded that students' public welfare concerns declined over the course of their engineering education. Perhaps the opposite trend is occurring with the undergraduate students from the summer program. It could be possible that their belongingness to what they understand engineering to be in the traditional sense that it is taught in educational programs has decreased, while not necessarily their belongingness to the sociotechnical, humanitarian side of engineering to which they were exposed. In this instance, it may not necessarily be a negative trend to see the overall decrease in their sense of belongingness as was reflected in the survey.

4.6 Implications

A new culture of engineering is forming from students who do desire a more sociotechnical, hands-on, broad curriculum that will expose them to opportunities for engaging communities. However, the results of this study demonstrate that creating this culture may not be optimally addressed through a summer program, or perhaps solely addressed through the program.

With this new culture, students are rejecting previous mindsets that were inherent within the engineering profession. Engineering will need to be represented in classrooms and institutions, as well as embraced by faculty and peers, as an industry that includes service-based, non-profit, community development pathways instead of mostly focusing on technically based, lucrative industries. While many students may be attracted to the later, it is important to be representative enough to where students can find future direction for a variety of options within the type of engineering they desire. Students are also challenging the historically exclusionary culture that has dominated engineering institutions by expressing a desire to work with a variety of backgrounds. Whereas culture may have previously rejected local knowledge and traditions in collaboration with the technical, scientific knowledge of engineers, students reflect a desire to incorporate other types of knowledge in conjunction with their engineering knowledge. However, there is a disconnect between what students desire to know and what they feel they do know and are prepared to address.

While rigor, on the one hand, is a source of pride and belongingness when students are able to master difficult course concepts, it is also a stressor. Engineering culture celebrates rigor and the heavy math and science skills it requires of its students. Historically, this has proven to be an exclusionary measure towards students who don't think along the same rigid, formulaic boundaries that the rigor culture enforces, assimilating everyone towards the same train of thought and eliminating diversity. But students demonstrate that they desire diversity of thought and while rigor has a beneficial element for challenging students, it should not be the standard to which everyone needs to meet. Additionally, it should not overwhelm students to the point where they question their ability to engineer, especially when it comes to courses that are not essential to the type of engineering they want to do. There needs to be a more holistic understanding of the tools that make engineers successful, including those skills that may not be learned in the classroom or the skills that are not technical in nature. If students were exposed to broader engineering curriculum, they would not assume that their success in engineering was solely dependent on how well they are able to master heavy math and science courses.

While much of the study implies that there are modifications needed for how engineering is represented in institutional spaces and overall mindsets, it also implies that the summer session did not produce the intended results of increasing belongingness for the students. Though curriculum wide changes may include several bureaucratic loops, modifying the summer session is a great first step towards attempting to increase sense of belongingness. In addition to a part two session and revising the conceptual lessons, the program can also better prepare students for focusing on the social aspects of their projects by teaching more concepts about how engineers can and have addressed social challenges and what knowledge they can rely on for doing so. While lecture sessions may discuss the importance and types of knowledge transfers and how to seek out power structures, it may not adequately teach enough solution-based techniques concerning how engineers can feel like they've successfully solved these problems with their engineering solutions.

4.7 Conclusion

In this study, students reflected on how engineering in a variety of different aspects fosters a sense or a lack of belongingness after participating in an immersive, sociotechnical summer program. Students desire an engineering program that has a sociotechnical approach, includes many hands-on activities and a broad curriculum, teaches a community driven design solution, and offers guidance and direction for a multitude of different engineering careers. Faculty also play a large role in students' sense of belongingness. Certain characteristics that faculty can embody that increase students' sense of belongingness are overall being more invested and engaged with their students. Students also desire an engineering culture that is more inclusive and diverse, presents more careers that help people and are fulfilling as opposed to focusing on the lucrative careers, and that promotes teamwork and collaboration instead of competition.

Additionally, the study demonstrates the mismatches that can occur between realms of belongingness and how students may feel a greater sense of belongingness in one area vs. another. It also highlights the contradiction of exposure to a program that includes many elements of engineering that students desire, but yet does not overall increase their sense of belongingness after participation. Future studies should focus on how this contradiction exists and if it is based in the fact that students mostly operate within a culture that does not perpetuate the sociotechnical, humanitarian engineering they wish to pursue and if they feel inadequately prepared to work as engineers in that space. Finally, the study presents an opportunity to reform an immersive, field-based, sociotechnical summer program geared at introducing students to the type of engineering they desire but does not reflect an outcome of increasing their overall belongingness to the many dimensions of engineering. The same evaluative process could also be used for other engineering programs in order to determine changes in sense of belongingness. A couple modifications to address would be an understanding of the engineering culture to which the student has currently been exposed and the type of engineering culture the program may promote in order to be mindful of any cultural mismatches that could result. Additionally, future work could explore control measures to account for any general changes in sense of belongingness that may not be due to the program but due to general loss of interest or other factors.

CHAPTER 5
CONCLUSION

5.1 Future Work

Engineering education has taken exciting steps towards making a more inclusive and diverse space. With research on concepts such as identity, funds of knowledge, and belongingness, educators can learn what elements they can incorporate into engineering education to further the success of students that are typically left out of the predominant engineering demographic. This thesis presents evidence that a focus on the concepts mentioned can create shifts in student’s persistence to complete their engineering education, their understanding in the engineering classroom, and their ability to feel like engineering is right for them. To further this trend, future work can explore broader demographics of students to discover more ways identity can be a useful tool, more funds of knowledge to scaffold students’ learning, and factors that can increase a students’ sense of belongingness to engineering that incorporate the shifting mindsets and interests of engineering students. Some possible suggestions could include how students respond to engineering activities that attempt to embrace aspects of their identities, a before and after study of how students respond to implementing funds of knowledge into the classroom space, and comparing and contrasting how students respond to different engineering programs that are geared at embracing the sociotechnical nature of engineering. The research has already shown how these factors have an influence over students, so the next steps are to start using the ideas in the classroom to understand how these factors can successfully merge with engineering curriculum.

5.2 Final Remarks

In concluding, this thesis will hopefully transform engineering education in an exciting new direction that doesn’t just consider success to be mastery of technical concepts. Students desire more from engineering, as well as who and what make a successful engineer. With so many initiatives that challenge monolithic spaces, it is imperative that engineering takes the needed steps to broaden its curriculum and embrace a changing dynamic. A profession that has long overlooked, excluded, and othered many people groups and types of knowledge is now seeing a trend towards a brand-new age of engineering!

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APPENDIX A

SUMMARY OF INTERVIEW PARTICIPANTS WITH DATES AND INITIALS REFERENCED IN THE STUDIES FROM CHAPTERS TWO AND FOUR

AA. Interview by Arielle Rainey. Personal Interview. ZOOM. 2021, February 22

AB. Interviews by Arielle Rainey. Personal Interview. ZOOM. 2021, May 19 (PRE) and 2021, August 12 (POST)

ABG. Interviews by Arielle Rainey. Personal Interview. ZOOM. 2021, May 7 (PRE) and 2021, August 16 (POST)

AG. Interview by Arielle Rainey. Personal Interview. ZOOM. 2021, August 3

AN. Interviews by Arielle Rainey. Personal Interview. ZOOM. 2021, May 15 (PRE) and 2021, August 16 (POST)

AR. Interview by Arielle Rainey. Personal Interview. ZOOM. 2021, August 16

B. Interview by Arielle Rainey. Personal Interview. ZOOM. 2021, April 14

BK. Interviews by Arielle Rainey. Personal Interview. ZOOM. 2021, May 21 (PRE)

D. Interview by Arielle Rainey. Personal Interview. ZOOM. 2021, February 24

EH. Interviews by Arielle Rainey. Personal Interview. ZOOM. 2021, May 2 (PRE) and 2021, September 14 (POST)

ER. Interviews by Arielle Rainey. Personal Interview. ZOOM. 2021, May 2 (PRE) and 2021, September 14 (POST)

G. Interview by Arielle Rainey. Personal Interview. ZOOM. 2021, May 12

GQO. Interviews by Arielle Rainey. Personal Interview. ZOOM. 2021, May 12 (PRE) and 2021, August 26 (POST)

MM. Interview by Arielle Rainey. Personal Interview. ZOOM. 2021, June 25

NG. Interviews by Arielle Rainey. Personal Interview. ZOOM. 2021, May 7 (PRE) and 2021, August 25 (POST)

Y. Interview by Arielle Rainey. Personal Interview. ZOOM. 2021, September 2

APPENDIX B

FIRST-GENERATION IDENTITY QUESTIONS

What pushes [first-generation] students towards pursuing post-secondary education and/or engineering?

1. What was your perspective on post-secondary education growing up?
2. What is your parent's educational background?
3. What were the deciding factors that played a role in your decision to pursue college? (How did you decide to go to college?) Your specific major?
4. Were there any downsides that you had to evaluate when making the decision to pursue college?
5. Who would you describe as the most influential beings in your decision to pursue college?

How do first-generation students view themselves when comparing themselves to other students?

1. How did you relate to your peers? How did you differ from your peers?
2. How would you describe your peer support system? What type of peer groups played a role in benefitting your college experience?
3. Did you ever have any negative encounters with college peers that stand out to you?
4. For those out of college: Do you still maintain contact with peers from college and how do those relationships still play a role in your current life?

How does environment and community impact the perspectives of first-generation students?

1. As you were in college, were there any experiences that stuck out to you in a positive way? How?
    a. What about in a negative way? How?
2. Who did you surround yourself with?
3. How would you describe the community that you grew up in?
4. What aspects of your community were most important to you?

5. While in college, were you still involved and/or connected to other communities outside of college? If so, what were they? Did you believe those connections to be a benefit or a hindrance as you worked towards your degree completion?

How do first-generation students' perspectives change towards post-secondary education throughout their time in school?

1. [As a first-generation student] How did your perspective on engineering change throughout your time in college?
    a. Why do you think this perspective changed or stayed the same?
2. In what ways did your educational experiences shape how you envisioned your future? Your career goals?
3. Were there moments when you doubted your choice in major and/or university? If so, what prompted those doubts?

How does identity play a role in engineering education?

1. When you think of the term identity, what does that mean to you?
2. What would you describe as your identity?
3. How was this identity shaped for you growing up?
4. What does this identity mean to you now?
5. Has that identity played a role in your decision to pursue college? Your specific major?

Follow-up questions:

1. How would you describe the term *cultural identity*, and what does that mean to you?
2. How would you define your cultural identity?
3. Growing up, did you see your cultural identity as beneficial or detrimental? What experiences shaped that perspective?
4. Throughout college, did you see your cultural identity as beneficial or detrimental? What experiences shaped that perspective?

APPENDIX C

PRE-FIELD SESSION UNDERGRADUATE INTERVIEW QUESTIONS

1. How do the faculty and academic professionals from [YOUR SCHOOL] play a role in how you see yourself as a successful engineer?
2. Are there certain aspects of the [YOUR SCHOOL] that play a role in how you see yourself as a successful engineer? If so, what are they?
3. Do you believe the faculty and academic professionals from [YOUR SCHOOL] play a role in connecting your experience to a future career that you desire? If so, how?
4. Are there certain aspects of the [YOUR SCHOOL] that play a role in connecting your educational experiences to a future career that you desire? If so, what are they?
5. Describe the top three characteristics that come to mind when you envision a program that solidifies that you belong in engineering.
6. Describe the top three characteristics that come to mind when you envision a faculty member or academic professional who helps you feel as though you belong in engineering.
7. Can you give me an example of an experience in engineering that made you feel like you belonged in the major and/or in the profession?
8. Can you give me an example of an experience in engineering that made you feel like you did not belong in the major and/or in the profession?

APPENDIX D

POST FIELD SESSION UNDERGRADUATE INTERVIEW QUESTIONS

1. How did the field session play a role in how you see yourself as a successful engineer?
2. Do you believe that the field session provided connection to a future career that you desire? If so, how?
3. How does the engineering learning from the field session compare with your experiences at Mines?
4. Describe the top three characteristics you observed throughout the field session that solidified that you belong in engineering.
5. Describe the top three characteristics you observed throughout the field session that caused you to question if you belong in engineering.
6. Did your experience influence your sense of belonging at [YOUR SCHOOL]? If so, how?

APPENDIX E

FIELD SESSION UNDERGRADUATE SURVEY QUESTIONS

I feel like an engineer.

I will feel like an engineer in the future.

I see myself as an engineer.

My parents see me as an engineer.

My instructors see me as an engineer.

My peers see me as an engineer.

I've had experiences in which I was recognized as an engineer.

I am interested in learning more about engineering.

I enjoy learning engineering.

I find fulfillment in doing engineering.

I am confident that I can understand engineering in class.

I am confident that I can understand engineering outside of class.

I can do well on exams in engineering.

I understand concepts I have studied in engineering.

Others ask me for help in engineering.

I feel comfortable in engineering.

I feel I belong in engineering.

I enjoy being in engineering.

I feel comfortable in my engineering classes.

I feel supported in my engineering classes.

I feel that I am part of my engineering classes.

I feel committed to engineering.

I feel sure about my choice of engineering as a major.

I feel welcomed by my engineering professors.

I feel welcomed by my peers in engineering.

I feel welcomed by my classmates in engineering.

APPENDIX F

INDIVIDUAL SURVEY RESULTS

Table F.1 Survey Results for Individual Students Pre and Post Field Session

Belongingness Type	**Pre**	**Pre**	**Pre**	**Pre**	**Pre**	**Pre**	**Pre**	**T**	**Post**	**Post**	**Post**	**Post**	**Post**	**Post**	**Post**	**T**
Participant ID for survey	36	35	33	31	28	27	26		36	35	33	31	28	27	26	
Classroom																
I feel welcomed by my classmates in engineering	3	5	4	5	3	4	3	27	3	5	3	4	3	5	3	26
Peers																
I feel welcomed by my peers in engineering	4	5	4	5	3	4	3	28	4	5	3	4	4		3	23
Faculty																
I feel welcomed by my engineering professors	4	5	4	5	4	4	2	28	2	5	3	4	4	5	3	26
Major																
I feel sure about my choice of engineering as a major	4	5	5	3	3	5	3	28	3	4	3	4	3	5	2	24
Profession																
I feel committed to engineering	4	5	5	4	4	5	4	31	4	4	4	4	3	5	4	28
Institution																
I feel that I am apart of my university	4	5	3	4	5	3	3	27	2	5	3	4	5	4	3	26
I feel supported by my university	4	5	3	5	5	3	2	27	2	5	2	4	5	4	2	24
I feel comfortable in my university	4	5	5	5	5	3	3	30	3	4	2	4	5	4	3	25
Overall																
I feel I belong in engineering	3	5	5	4	4	5	3	29	2	4	3	3	3	5	3	23

APPENDIX G
SUPPLEMENTAL FILES

An educational video on funds of knowledge accompanies the script detailed in Chapter 3. The title of the video is Funds_Of_Knowledge_Final_01072022 and it has been uploaded as a supplemental file in ProQuest. This film was edited and produced by KO Illustrations and features an introduction, two scenes depicting students using their funds of knowledge, and a conclusion. The introduction discusses the concept of funds of knowledge, the scenes depicting funds of knowledge demonstrate the benefit of having tinkering knowledge and resourcefulness, and the conclusion provides a summary of useful applications for instructors to include funds of knowledge in curriculum.

APPENDIX H

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Submission: 17

Arielle Marie Rainey

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