Thinking Like an Engineer: Interrogating the Epistemic Hierarchy of a Professional Engineering Community of Practice

Dissertation

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Abstract

What it means to "think like an engineer" and what "counts" as engineering knowledge is a foundational part of engineering culture. What engineers value as knowledge and how they act on that knowledge impacts nearly every aspect of engineering design and practice as well as who enters and persists in engineering. Within engineering, researchers have revealed that what "counts" as engineering knowledge and what is considered "thinking like an engineer" have been socially constructed in hierarchical ways. For example, assumptions around what is considered legitimate engineering knowledge and ways of knowing consistently construct technical or quantifiable knowledge and analytical or rational ways of knowing as superior.

These hierarchies are problematic because they 1) function in ways that devalue social considerations (e.g., social welfare, social impact) from engineering work and 2) have been constructed by the dominant social groups in engineering (i.e., White, cisgender, men) and work to maintain the exclusivity of engineering. In other words, when one does not identify with the dominant ways of knowing in engineering or is presumed to not have the abilities associated with valued engineering knowledge and ways of knowing based on gendered or racialized stereotypes (e.g., men are rational, women are empathetic), they can be excluded from engineering. As such, the types of

knowledge and ways of knowing that are constructed as superior in engineering impact who enters and persists within engineering and how engineers consider (or don't consider) social wellbeing as part of their professional work.

Thus, in order to create a more socially conscious and inclusive engineering field, core assumptions about engineering knowledge and ways of knowing must be interrogated and expanded. In this interpretive study informed by feminist theories, I used qualitative methods to approach the following research questions, *1) What are the shared beliefs within a structural engineering community of practice that engineers use to justify (or resist) the epistemic hierarchy of engineering practice, 2) How do the epistemic practices within a structural engineering community of practice relate to the shared beliefs used to justify (or resist) the epistemic hierarchy of engineering, and 3) How do engineers within a structural engineering community of practice relate their engineering identity to the epistemic hierarchy of engineering?* To do this, I employed a conceptual framework that situates beliefs about engineering knowledge and ways of knowing, identity, and epistemic practices as negotiated within an engineering community of practice. Drawing on feminist epistemologies and empirical evidence from engineering education research, I also approach this study with the theoretical understanding that the epistemic hierarchy of engineering is "baked" into engineering communities of practice.

To answer my research questions, I interviewed 10 engineers from one structural consulting engineering community of practice using a semi-structured interview protocol featuring a graphic elicitation exercise. Guided by the research questions and the conceptual framework, the data analysis consisted of an inductive coding approach to condense the data around the constructs of interest (i.e., beliefs, identity, and epistemic practices) and to develop a codebook that was applied to all interview transcripts. Additionally, I used detailed analytic memos to help make sense of the complex interaction between aspects of the participants' engineering identity and social identities.

From the analysis, I found that the epistemic hierarchy of engineering was pervasive in the professional engineering community of practice and reproduced using beliefs related to what is assumed to be the definition of engineering and assumptions about the role of objectivity in engineering. Unfortunately, the most pervasive shared beliefs used to resist the epistemic hierarchy of engineering are rooted in capitalistic and neoliberal ideology, which is troublesome because it is often at odds with social justice and equity initiatives. Finally, this research demonstrated the engineers who identified as women or gender non-binary were more likely to strongly identify with normative ways of knowing in engineering (i.e., analytical thinking) than their majority counterparts, which provides insight into the role of privilege in the way that engineering identity is negotiated within a community of practice in relation to the epistemic hierarchy of engineering. In other words, it indicates that being able to identify with engineering, to be identified by others as an engineer, and to be able to strongly connect that identity to ways of knowing like creativity or empathy is a privilege

Ultimately, this work implies that to disrupt normative ways of knowing in engineering, there is a need to make explicit how the deeply pervasive, limited, and exclusionary epistemic hierarchy of engineering is reproduced. Specifically, I recommend making space for students and professionals to critically reflect on what it means to think like an engineer, the myth of objectivity and value-neutrality in engineering, the role of authority in their decision making, how capitalist agendas and neoliberal ideology can lead to unjust outcomes, and the implications of their identification with certain types of knowledge and ways of knowing in engineering. Additionally, for engineering educators, I recommend we deeply integrate "other" ways of knowing throughout all aspects of the engineering curricula. By doing so, we can provide powerful opportunities for students and professionals to expand their conceptions of what it means to think like an engineer, which will lead to a more socially conscious and inclusive engineering field.

Dedication

To Ross and Ben

Acknowledgments

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Dringenberg, E., **Kramer, A**. (2019) The Influence of Both a Basic and In-Depth Introduction of Growth Mindset on First-Year Engineering Students' Intelligence Beliefs. *International Journal of Engineering Education. 35*(4), 1052-1063

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Fields of Study

Major Field: Engineering Education

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Chapter 1. Introduction

What it means to "think like an engineer" and what "counts" as engineering knowledge is a fundamental part of engineering culture (Adams et al., 2006; Godfrey & Parker, 2010). What engineers value as knowledge and how they act on that knowledge has a substantial impact on nearly every aspect of engineering design (Kant & Kerr, 2019) as well as on who enters and persists in engineering (Riley et al., 2014). Within engineering, researchers have revealed that what "counts" as engineering knowledge and what is considered "thinking like an engineer" have been socially constructed in hierarchical ways (Pawley, 2012; Riley et al., 2014). For example, assumptions around what is considered legitimate engineering knowledge and ways of knowing consistently construct technical or quantifiable knowledge and analytical or rational ways of knowing as superior (Cech, 2014; Faulkner, 2000; Godfrey & Parker, 2010).

The way that value is placed on certain types of knowledge and ways of knowing in engineering over others is important because researchers have shown that the resulting epistemic hierarchy of engineering is limited and perpetuates exclusion (Cech, 2014; Cech et al., 2017; Faulkner, 2000, 2007; Pawley, 2012; Riley et al., 2014). For example, the way that engineering knowledge and ways of knowing that are associated with the "technical" are valued more than those associated with the "social" leads to a culture of disengagement that devalues social welfare and ethical considerations during engineering work (Cech, 2014). This is problematic given that the first cannon of the National Society of Professional Engineers Code of Ethics states to “hold paramount the safety, health, and welfare of the public” (NSPE, 2018). Furthermore, the way that engineers place value on certain types of engineering knowledge or ways of knowing over others can limit how engineers make and communicate design decisions (Dringenberg et al., 2021) and limit their ability to understand their own subjectivity during problem-solving (Godfrey & Parker, 2010).

Additionally, scholars have concluded that the assumptions about engineering knowledge and ways of knowing that underpin engineering culture have been constructed by the dominant social groups (i.e., White, cisgender men) and work to maintain the exclusivity of engineering (Cech et al., 2017; Riley et al., 2014). In other words, when one does not identify with the dominant ways of knowing in engineering or is presumed to not have the abilities associated with valued engineering knowledge and ways of knowing based on gendered or racialized stereotypes (e.g., men are rational, women are empathetic), they can be systemically excluded from engineering. As such, the socially constructed epistemic hierarchy in engineering can impact who enters and persists within engineering, as well as how engineers consider (or don’t consider) social welfare as part of their professional work.

In order to create a more socially conscious and inclusive engineering field, core assumptions about engineering knowledge and ways of knowing must be interrogated and expanded. As engineering educators prepare students for engineering practice, it is essential that we understand and critically interrogate the shared beliefs and practices that reproduce the problematic assumptions around what "counts" as knowledge in engineering and what it means to "think like an engineer."

I use several key terms operationalized in specific ways throughout this dissertation. Refer to Table 1 for a list of key terms. These terms will be further expanded upon in Chapter 2.

Table 1: Key Terms

Key Term	**Meaning**
Engineering Epistemology	Theories about engineering knowledge and ways of knowing
Epistemic Hierarchy	Socially constructed arrangement of value placed on types of engineering knowledge and ways of knowing (e.g., math and science over writing and communication, analytical thinking over creativity and empathy)
Personal Epistemology	Personal beliefs about knowledge and ways of knowing
Engineering Identity	A role identity that is negotiated within a sociocultural context and can have different meanings, interpretations, or salience based on aspects of social identity

Purpose

The purpose of this exploratory qualitative study is to interrogate the epistemic hierarchy of engineering by uncovering the shared beliefs within a professional engineering community of practice used to justify (or resist) the epistemic hierarchy of engineering. Since shared beliefs are a way to understand engineering culture (Godfrey & Parker, 2010), uncovering the shared beliefs of engineers within a community of practice furthers our understanding of how the epistemic hierarchy of engineering is culturally reproduced within a specific context. According to Beddoes et al. (2017a), in order to make sense of practicing engineers' beliefs about knowledge and ways of knowing, one must also consider their practices, identity, and context (i.e., community of practice). Thus, I also aim to understand how self-reported epistemic practices relate to those shared beliefs as well as how engineers negotiate their engineering identity within the context of an engineering community of practice. Furthermore, exploring engineering identity in relation to social identity (e.g., gender and race) is important to further our understanding of how the epistemic hierarchy of engineering can perpetuate exclusion. Through the findings of this work, I make explicit the assumptions that engineers hold that reproduce the limited and exclusionary epistemic hierarchy of engineering.

Research Questions

In this study, I address the following research questions:

1. What are the shared beliefs that engineers within a structural engineering community of practice use to justify (or resist) the epistemic hierarchy of engineering?
2. How do the self-reported epistemic practices of engineers within a structural engineering community of practice relate to the shared beliefs used to justify (or resist) the epistemic hierarchy of engineering?
3. How do engineers within a structural engineering community of practice relate their engineering identity to the epistemic hierarchy of engineering?

This contribution is warranted because while previous research has provided evidence that there is a socially constructed epistemic hierarchy in engineering, with this work I extend our scholarly understanding of the shared beliefs and practices of practicing engineers that reproduce the problematic assumption around what “counts” as engineering knowledge and what it means to “think like an engineer.” Furthermore, I provide insight into how the epistemic hierarchy of engineering relates to the identity of engineers and how they negotiate that identity within a community of practice.

Implications

This work advances the field of engineering education through a greater understanding of the beliefs, reported practices, and identities of professionals in engineering, which is needed to 1) help prepare students for engineering practice, and 2) contribute to the much-needed discussion of equity and inclusion in engineering by interrogating problematic epistemological assumptions that contribute to the exclusion of individuals in engineering. Through this work, engineering educators can develop targeted strategies for students and professionals aimed at expanding conceptions of what it means to think and know like an engineer, which is essential to fostering a more socially conscious and inclusive engineering field.

Chapter Overview

In Chapter 1, I provide an overview of the purpose, research question, and implications of this work. In Chapter 2, I provide a detailed literature review synthesizing how I came to the understanding that the socially constructed epistemic hierarchy of engineering is limited and perpetuates exclusion. I also provide justification for the conceptual framework employed in this research to further interrogate the epistemic hierarchy of engineering utilizing the community of practice (CoP) framework to explore the beliefs, reported practices, and identities related to engineering knowledge and ways of knowing of engineers. In Chapter 3, I provide a detailed description of the interpretive qualitative research methods informed by my feminist perspective employed in this research. Specifically, I discuss the context and participants, data collection, data analysis, and quality procedures. In Chapter 4, I present the findings in response to the three research questions. Finally, in Chapter 5, I discuss the findings along with the implications of this research for a variety of stakeholders, future work, and end with the conclusions of this dissertation.

Chapter 2. Literature Review

In this literature review, I provide an overview of the relevant literature used to situate this research. First, I provide a detailed discussion of how I came to the understanding that the socially constructed epistemic hierarchy of engineering is limited and perpetuates exclusion. I then provide a discussion justifying the conceptual framework employed in this research to further interrogate the epistemic hierarchy of engineering. The conceptual framework draws on the theory of community of practice to explore the beliefs, reported practices, and identities of engineers within a sociocultural context.

The Epistemic Hierarchy of Engineering

The epistemological assumptions that engineers hold about what "counts" as engineering and what it means to "think like an engineer" are central to engineering culture (Godfrey & Parker, 2010; Kant & Kerr, 2019). Consistently researchers have shown that what "counts" as engineering knowledge and what it means to "think like an engineer" is constructed in ways that place more value on knowledge associated with the "technical" than with the "social" and analytical or rational thinking than with ways of knowing like empathic thinking or creative thinking (Cech, 2014; Dringenberg et al., 2021; Faulkner, 2000; Godfrey & Parker, 2010; Pawley, 2012; Riley et al., 2014). Refer to Figure 1 for a visual example of the epistemic hierarchies of engineering based on findings from the extant literature.

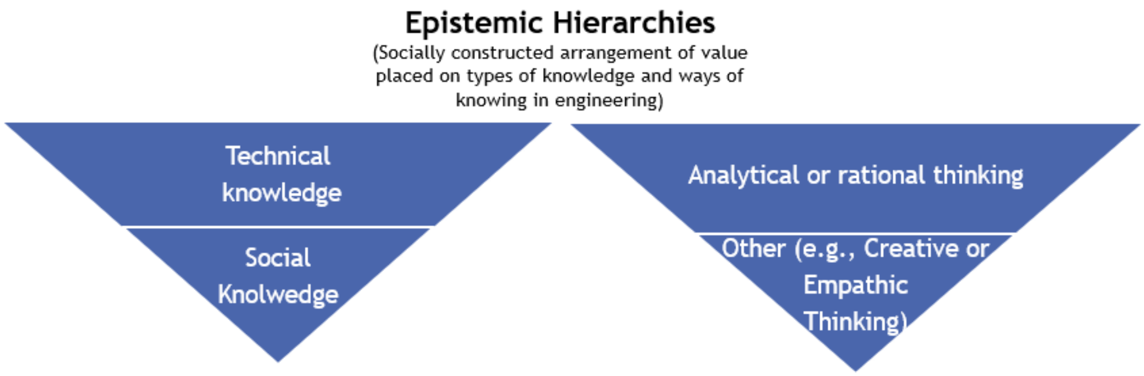

Figure 1: Epistemic Hierarchies in Engineering
Note: based on findings from extant research

In the following section, I provide further discussion of how certain types of knowledge and ways of knowing in engineering have been constructed as superior and how the resulting epistemic hierarchy of engineering is limited and perpetuates exclusion. To be clear, I define an epistemic hierarchy as a socially constructed arrangement of value placed on types of knowledge and ways of knowing in engineering. Specifically, in the following section I discuss how 1) the epistemic hierarchy of engineering is rooted in Western epistemologies of science, 2) the feminist critique of epistemologies of science provides a critical lens for understanding the implications of the epistemic hierarchy of engineering, and 3) that the epistemic hierarchy of engineering is limited and perpetuates exclusion.

The epistemic hierarchy of engineering is rooted in Western epistemologies of science

Engineering epistemology is dominantly associated with the sciences (Cech et al., 2017; Figueiredo, 2008; Kant & Kerr, 2019). Epistemology refers to a main branch of philosophy that explores theories about the nature of knowledge and has been a focus of philosophers dating back to the ancient Greeks (Britannica, 2020). Epistemological considerations include questions such as, *what is knowledge?, how is knowledge justified?, and what are sources of knowledge?* Traditionally, Western philosophers have studied epistemology from an individualistic point of view. In other words, they were concerned with the individual "knower" and an individual's ability to access knowledge. Evolving through Western philosophy, the epistemology of science has taken prominence and typically defines scientific knowledge as an individual's belief based on reason and empirical evidence gathered and holds paramount notions of rationality, objectivity, and value-neutrality in the pursuit of knowledge (Wenning, 2009). Additionally, the individualistic focus of epistemologies of science has manifested in idealistic (and incorrect) notions of the "great man" scientist dispassionately working in isolation to uncover knowledge of nature's true reality (Kant & Kerr, 2019).

Although scholarship on epistemology and the epistemology of science is well-established, philosophical studies of engineering epistemology are relatively sparse. A reason attributed to the lack of philosophical scholarship on engineering epistemology is due to a long-held misconception that engineering is merely applied science and thus just an extension of epistemologies of science (Figueiredo, 2008; Kant & Kerr, 2019). Although there is no formal or agreed-upon answer as to what constitutes engineering knowledge amongst scholars of engineering epistemology (Kant & Kerr, 2019), there is consensus that engineering epistemology should be distinct from the sciences. Scholars highlight the usefulness of engineering knowledge and the unique features of the design process (Bucciarelli, 2003; Figueiredo, 2008; Vincenti, 1992). Additionally, multidisciplinary approaches to engineering epistemology tend to focus on the relationship between engineering, science, and technology, as well as the relationship between engineering and society (Kant & Kerr, 2019). Specifically, scholars argue that engineering processes, particularly design, are social processes and that engineering knowledge is (or at least should be) profoundly linked with socially determined concerns and goals (Bucciarelli, 2003; Kant & Kerr, 2019). In other words, the problems engineers solve and how they solve them are social processes that are deeply relational to society.

However, despite these philosophical assertations that engineering is distinct from the science, engineering is still strongly linked with epistemologies of science (Cech et al., 2017; Kant & Kerr, 2019). As such, the types of knowledge and ways of knowing associated with rationalism, objectivism, and value-neutrality are deeply valued in engineering, in part, based on their association with epistemologies of science

The feminist critique of epistemologies of science provides a critical lens for understanding the implications of the epistemic hierarchy of engineering

Given the pervasive association of engineering with the sciences, engineers can learn from the feminist critique of epistemologies of science and scientific practices. Feminist epistemologists and feminist science and technology scholars provide a critical lens through which engineers can understand the implications of constructing certain types of knowledge and ways of knowing as superior.

Feminist scholars have long challenged traditional Western views of epistemology and brought a much-needed critique to normative ways of knowing in epistemologies of science (for example, Harding, 1991; Longino, 1987). Starting in the 1970s, feminist social scientists and biologists started to argue against the sexist and androcentric practices of the sciences (Harding, 1991). Specifically, they argued that women did not have a voice in research practices and that research questions were never asked from the perspective of women. For example, Belenky and colleagues (1986) argued that “knowledge and truth that are accepted and articulated today have been shaped throughout history by the male-dominated majority culture” (loc. 295, eBook). Out of these early criticisms of scientific practices grew the development of feminist epistemologies and the field of feminist science and technology studies.

Feminist epistemologies have provided critical insight into the limitations of epistemologies of science. Although there is no singular feminist epistemology, what can be gleaned from the collective work of feminist epistemologists is that what “counts” as knowledge and what is considered as legitimate ways of knowing is greatly influenced by societal forces (e.g., gender and race), is relational to power, and results in knowledge that benefits the dominant social group (Harding, 1991; Longino, 1987, 2002; Sprague, 2016). Although not a complete list, feminist epistemologies are often grouped by what Harding (1991) defined as the three main branches of feminist epistemology; feminist empiricism, standpoint theory, and postmodern feminism.

Feminist empiricism does not necessarily take issue with the scientific method itself; they still believe in objectivism and that knowledge can be accessed through empirical evidence in the tradition of critical realism (Sprague, 2016). However, they do argue that the biases of those conducting research and those funding research have resulted in incomplete or misguided scientific practices. Feminist empiricists believe that these issues can be overcome by addressing researcher bias and being transparent about the political agendas behind the work (Harding, 1991).

Standpoint theorists argue that knowledge itself is indeed socially situated and shaped by social relations, particularly those of gender, race, and class. They argue that knowledge is grounded in local and historical contexts and ultimately stems from one's social position (Sprague, 2016). In other words, in a stratified society by gender (and other categories of social difference), our position shapes what we know and how we know it. Standpoint theorists reject traditional notions of objectivity in the sciences. Feminist standpoint theorists are largely interested in the standpoint of women since they argue that research and theory have largely ignored women (Harding, 1991). From standpoint theory also came the controversial concept of epistemic advantage, which means that those from unprivileged social positions may have a less distorted (i.e., better) understanding of a social reality under investigation (Rolin, 2009). For example, if you are trying to understand sexism in a given context, women would have the epistemic advantage, meaning that through their lived experience they have a greater understanding of the sexism that is occurring.

Finally, postmodern feminists take an epistemological position associated with radical social constructionism meaning that they don't consider knowledge as necessarily "out there in the empirical world," but rather as something that researchers "give order to" through the application of frameworks based on subjective perceptions (Sprague, 2016, p.39). In other words, the discovery of knowledge is an illusion that is falsely used to order society into socially constructed standards or norms. Inspired in large part by the work of French philosopher Michel Foucault (1980), postmodern feminists view knowledge and power as inextricably linked; “power is enacted through the organization of knowledge and knowledge is constructed as a form of domination” (Sprague, 2016, p. 40). Thus, the goal of postmodern feminists is to deconstruct and destabilize the oppressive hierarchical categories or binaries that have led to gender inequality. For example, postmodern feminists reject any essentializing or binary notions of gender and argue that is a socially constructed illusion.

Scholars of feminist science and technology studies have provided critical insight into the limitations of science practices. Drawing on feminist epistemologies**,** feminist scholars in the field of science and technology studies (STS) used critical theory to explicitly explore the hidden assumptions within science and technology (and recently engineering) that perpetuate inequity (Riley et al., 2009). Feminist STS scholars reject assumptions of objectivity and value-neutrality in scientific practices claiming that science is inextricably linked with political goals and agendas. They argue that the concept of value-neutrality in science is indeed impossible as the pursuit of scientific knowledge is governed by the conflicting social agendas of those struggling to gain or maintain power (Harding, 1991). Additionally, feminist STS scholars interrogate the power relations that influence how science is practiced (Longino, 1987), particularly, by questioning harmful dichotomies (e.g., man/woman) that lead to unclear or inappropriate outcomes and the erasure of certain individuals. Feminist STS scholars also point their gaze on the outcome of scientific or technological practices by asking questions about how the development of certain technologies benefit or disadvantage certain populations or groups based on their social identities (Riley et al., 2009).

In recent years, a growing number of researchers within the engineering education community have aligned themselves with feminist STS scholars (for example, Faulkner, 2000; Pawley, 2009). These scholars have turned a critical lens to the power relations through which engineering is practiced and the hidden assumptions within engineering that lead to inequity (findings of their work are presented in the following section). Indeed, learning from feminist science and technology studies was identified as a transformative way to bring feminism into engineering education (Riley et al., 2009). Ultimately, these feminist scholars provide a critical lens for understanding the implications of the epistemic hierarchy of engineering

The epistemic hierarchy of engineering is limited and perpetuates exclusion

In line with the mission of feminist science and technology scholars, I draw on empirical evidence from extant literature to showcase how the socially constructed epistemic hierarchy in engineering is limited and perpetuates exclusion.

The epistemic hierarchy of engineering is limited. First, researchers have consistently empirically shown that in general, what "counts" as engineering knowledge is only what is considered to be quantifiable, objective, and reflective of "true" reality (for example, Godfrey & Parker, 2010; Montfort et al., 2014). The problem with the emphasis on quantifiable, objective knowledge is that it does not allow for the subjective nature and the social complexities involved in solving problems. When engineering problem solving is thought to be solely based on objective scientific principles, engineers see engineering problem solving as systematic and dispassionate thus excluding the human dimension from engineering problem-solving (McNeill et al., 2016). In addition, the narratives surrounding engineering as problem-solving using applied math and science leaves critical considerations such as who is defining the engineering problem and who is benefiting from the engineering solution as out of the bounds of engineering knowledge (Pawley, 2009, 2012).

Similarly, the social-technical divide that is pervasive in engineering placing more value on the technical than with the social (Faulkner, 2000) leads to what Cech (2014) has described as a culture of disengagement in engineering. Specifically, Cech's research (2014) showed that engineers consistently prioritize math and science over ethical or social concerns. Further, over the course of an engineering student's education and into their career, the prioritization of math and science knowledge over ethical and social knowledge increases (Cech, 2014). Thus, over time engineers are socialized into the epistemic hierarchy of engineering placing value on math and science knowledge above all else. Cech (2014) points out how this leads to a lack of consideration for social well-being and ultimately creates an epistemic culture of social disengagement in engineering.

Additionally, the way that certain ways of knowing are constructed as superior in engineering (e.g., rational and analytic thinking) can limit the abilities of engineers to solve complex problems and make subjective decisions. Although rationalistic, analytical decision-making methods are certainly important in engineering work, it is also unrealistic to assume that they are the only ways of knowing needed to solve engineering problems. For example, it's long been acknowledged that the objective and decontextualized problems presented in engineering sciences courses do not account for the reality of the subjective nature of real-world engineering problems (Godfrey & Parker, 2010). Indeed, researchers studying beliefs about engineering decision-making have revealed that engineering faculty typically only teach rationalistic problem-solving approaches despite the belief that they are inherently limited (Dringenberg et al., 2021). In addition, when engineers internalize the expectation of rational, objective decision-making when faced with complex problems, they often fail to acknowledge the uncertainty or subjectivity of their assumptions and judgments (Godfrey & Parker, 2010). This lack of self-awareness is dangerous if engineers do not recognize (or are taught how to recognize) how their own biases, belief systems, or subjective interpretations influence their engineering work.

The epistemic hierarchy of engineering perpetuates exclusion. Drawing on feminist theory, socially constructed hierarchies are inherently oppressive because they are used in ways that sort and rank people (Sprague, 2016). Within engineering education, researchers have begun to explicitly explore the exclusionary impact of the epistemic landscape of engineering. One such study found that a high-achieving engineering student felt alienated from his engineering program due to a mismatch in epistemological aspects of his identity and the "intellectual climate" of his program (Danielak et al., 2014). A major implication of the study was that epistemological considerations should be a focus in persistence and retention studies in engineering. Similarly, researchers that explicitly considered the exclusionary implications of epistemological assumptions, empirically showed that the dominance of scientific epistemologies in science, engineering, and health translated into very real disadvantages for indigenous students (Cech et al., 2017). Cech and colleagues (2017) concluded that “epistemologies may serve as a seemingly benign but deeply consequential source of structural and cultural disadvantages for underrepresented groups" (p. 744). Finally, the social-technical divide, with technical being constructed as “real” engineering, was shown to have gendered consequences (Faulkner, 2007). Specifically, since masculinity is more often associated with the technical side of engineering, the result was that it was easier for men to be considered by themselves and by others as “real” engineers.

Additionally, assumptions that engineering is only for rational, analytically minded people reinforce the oppressive way that intelligence and smartness have been constructed in engineering. In Western culture, intelligence is typically considered as an innate, analytical ability (Sternberg, 2002). Like all social constructs, intelligence has been constructed by the dominant group of society and thus has consequences for minoritized groups. For example, fields that are believed to require innate ability have the lowest representation of non-White and non-male participation (Leslie et al., 2015). The consequences of smartness or intelligence (typically considered to be innate, analytical ability) is particularly salient in engineering because engineers are broadly recognized as “smart” (National Academy of Engineering, 2008; Sochacka et al., 2014). Yet, who gets recognized as smart is biased (Hatt, 2012; Leonardo & Broderick, 2011) and perceptions about what it means to be “smart” can act as a gatekeeper in engineering (Carroll et al., 2019). For example, empirical evidence within engineering education has shown that students believe that being perceived as smart is important for social positioning and provides access to both formal and informal opportunities (Dringenberg et al., 2022). Additionally, stereotypes about ability have resulted in non-White and non-male individuals often being falsely presumed to be less competent (i.e., less rational, less analytical) than their majority counterparts (Gutiérrez y Muhs et al., 2012). Within engineering practice, a study found that engineers who identify as women and as engineers of color are more likely to experience the "prove it again" bias indicating that they are often falsely presumed to have less analytical abilities than the engineers that identify as White men (Williams et al., 2016). For clarity, Table 2 provides a summary with examples of the limited and exclusionary implications of the epistemic hierarchy of engineering.

Table 2: Examples of the Limited and Exclusionary Epistemic Hierarchy

Epistemic Hierarchy	**Limitations**	**Exclusionary Implications**
Engineering Knowledge: Technical over social; Quantifiable over unquantifiable	Limits considerations for social welfare being part of "real" engineering work	Exclusionary to those who value type of knowledge not traditionally prioritized in engineering
Way of knowing: Analytical/rational over all else (e.g., creativity, empathy)	Limits considerations for individual biases or subjectivity in engineering work. Limits ability to express alternative ways of thinking.	Exclusionary to those who have historically not been recognized as having intellectual traits that are associated with valued ways of knowing

In sum, the epistemic hierarchy of engineering is limited and perpetuate exclusion. Thus, in order to create a more socially conscious and inclusive engineering field, the epistemic hierarchy of engineering must be further interrogated, and what “counts” as engineering knowledge and legitimate ways of knowing in engineering must be expanded.

Conceptual Framework

To further interrogate the epistemic hierarchy of engineering, we must understand the shared beliefs that engineers use to justify (or resist) normative ways of knowing in engineering. Shared beliefs are reflective of cultural norms and assumptions in engineering (Godfrey & Parker, 2010). Thus, empirical evidence of practicing engineers’ beliefs about engineering knowledge and ways of knowing add to our collective understanding of the cultural assumptions that reproduce the epistemic hierarchies of the profession. In this research, I employ a conceptual framework adapted from Beddoes et al. (2017a) and their study on the personal epistemologies (i.e., beliefs about knowledge and ways of knowing) of practicing engineers. According to Beddoes et al. (2017a), engineers’ beliefs about knowledge and ways of knowing are best understood through epistemic practices, alongside identity, and must account for context. As such, I used the theory of community of practice to provide the sociocultural frame to contextually explore the beliefs, practices, and identities of engineers. Finally, built into the framework is the assumption that the epistemic hierarchy of engineering is “baked” into engineering communities of practice, which is based on the extant literature provided in the previous section (*Chapter 2, The Epistemic Hierarchy of Engineering*) and confirmed during data collection. Refer to Figure 2 for an overview of the conceptual framing of this study. In the following section, each component of the framework will be discussed in detail.

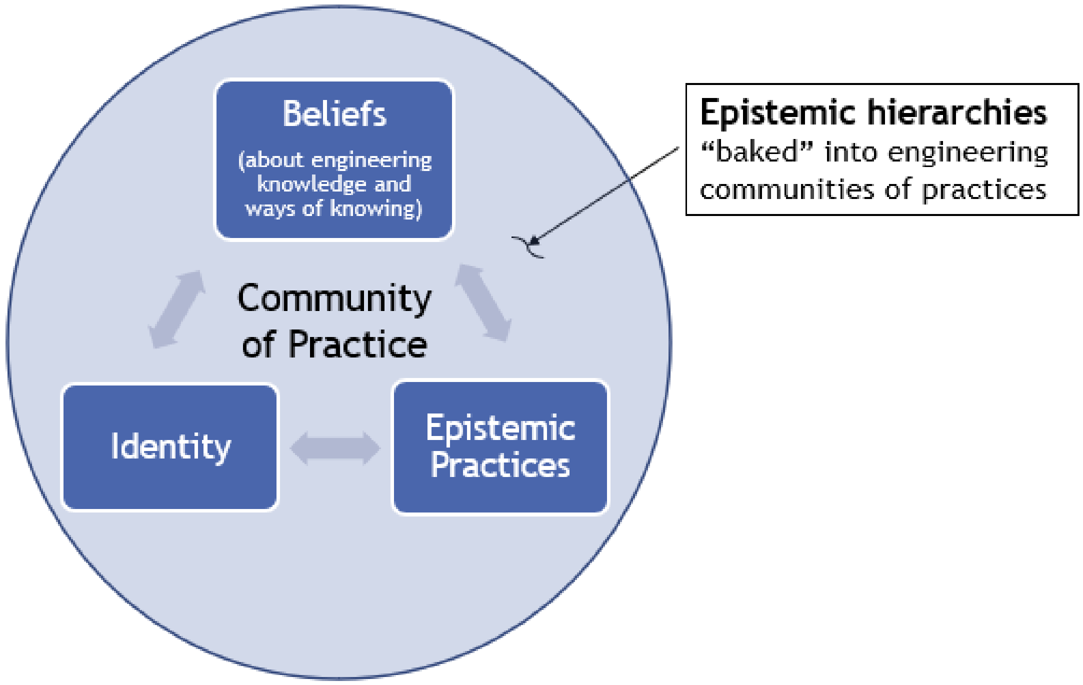

Figure 2: Conceptual Framework
Note: Adapted from Beddoes et al. (2017a)

Beliefs about engineering knowledge and ways of knowing

Beliefs about knowledge and ways of knowing are complex and studied in many ways. Beliefs are complex, dynamic, and contextual and can be difficult to study (for example, Kramer, Morris, et al., Forthcoming; Pajares, 1992). Therefore, it is not surprising that beliefs about knowledge or ways of knowing (also referred to as personal epistemology or epistemological beliefs) have been studied in many ways. In fact, within educational psychology and cognitive development literature, there is no singular theory or consensus regarding methods or frameworks for the study of beliefs about knowledge and ways of knowing (Hofer & Pintrich, 1997). For example, they have been described as stages of development (e.g., Belenky et al., 1986; Kitchener & King, 1981; Perry Jr, 1970), sets of beliefs (Schommer, 1990), cognitive processes (e.g., Barzilai & Zohar, 2016; Kuhn, 2000), and multi-dimensions stances (Hofer & Pintrich, 1997).

Research exploring beliefs about knowledge and ways of knowing is rooted in developmental theories. William Perry, starting in the 1950s, began to develop a scheme for what he described as the ethical and intellectual development of college students (Perry Jr, 1970). His scheme (or framework) consisted of nine positions starting with a basic dualistic view of knowledge (i.e., right or wrong) to a relativistic view of knowledge (i.e., committing to a position/solution while taking into account context and personal values). Since then, many scholars have expanded his work with developmental theories of their own. Notably, Mary Belenky and colleagues (1986) created a developmental framework focused on women's ways of knowing in response to the mostly male (and White, affluent) Harvard students from Perry's original study. The Belenky et al. (1986) framework consisted of five stages ranging from what they describe as silence to constructed knowledge. Despite the differences between the varying developmental frameworks, most frameworks position intellectual development ranging from some variation of absolute knowing to contextual knowing.

In response to the limitations of the developmental models, researchers began to theorize epistemological beliefs as a multidimensional set of beliefs as opposed to a single unidimensional structure on which people linearly progress. In other words, researchers argue that instead of progressing through unidimensional stages of intellectual development, beliefs about knowledge and ways of knowing can vary and develop differently across different dimensions of knowledge and ways of knowing. For example, Schommer's (1990) framework of epistemological beliefs consisted of beliefs related to the source of knowledge, the simplicity of knowledge, and the certainty of knowledge as well as beliefs related to the nature of learning and the nature of intelligence. Further, she found that certain dimensional beliefs resulted in specific outcomes (e.g., beliefs in the certainty of knowledge lead to inappropriate absolute conclusions). Amongst researchers who use dimensional models, there is often dispute about which dimensions should be considered in epistemological beliefs research.

Epistemological beliefs have also been theorized as different aspects of cognitive processes or as a way of epistemic thinking (Barzilai & Zohar, 2016; Kuhn, 2000). Although epistemic thinking is highly complex, it's been theorized to encompass different aspects of cognition and metacognition, which together can be used to analyze epistemic thinking. One such framework used to explore epistemic thinking consists of four facets; epistemic cognition (e.g., assessing the validity of claims), epistemic metacognitive skills (e.g., planning information gathering), epistemic metacognitive knowledge (e.g., knowledge about source reliability), epistemic metacognitive experiences (e.g., epistemic surprise) (Barzilai & Zohar, 2016). Similar to the developmental models, research in this space tend to focus primarily on how epistemic thinking relates to student learning and the development of self-regulated learning strategies.

I operationalize beliefs about knowledge and ways of knowing as dimensional and use them to provide insight into broader cultural beliefs, norms, and values. In line with the work of Beddoes et al. (2017b), I am interested in beliefs about knowledge and ways of knowing as a means of gathering empirical evidence to provide insight into broader cultural beliefs, norms, and values. Therefore, since I am not interested in explicitly relating such beliefs to learning, the intellectual developmental and cognitive process frameworks are not appropriate. Thus, I approach the construct of beliefs in this research using the dimensional understanding of beliefs about knowledge and ways of knowing offered by Hofer and Pintrich (1997). Hofer and Pintrich (1997) developed their understanding of personal epistemology based on an extensive review of epistemological theories and build on the work of Schommer (1994). Specifically, Hofer and Pintrich (1997) offer four key dimensions:

- source of knowledge (nature of knowing),
- justification for knowledge (nature of knowing),
- simplicity of knowledge (nature of knowledge), and
- certainty of knowledge (nature of knowledge)

Additionally, I consider the dimension,

- sociality of knowledge

Beddoes, Montfort, and Brown (2017b) added the dimension of the sociality of knowledge in their personal epistemologies research based on their assertion that it is imperative to understand how individuals explicitly situate their knowledge within social systems and that their beliefs are context-dependent and domain-specific.

There is a need for research on the beliefs about knowledge and ways of knowing for practicing engineers. In this research, I focus on the beliefs of practicing engineers. I do this because there is relatively little research focused on engineering practice, which is needed for a more robust evidence-based understanding of professional work and professional culture (Stevens et al., 2014). Specific to research in the personal epistemologies of practicing engineers, I found very little research in this space. This is primarily because personal epistemology research has traditionally been the focus of educational psychologists and the bulk of the research in the field is concentrated on student learning. For example, within engineering education, researchers have traditionally used educational psychology frameworks to explore how the epistemological beliefs of students relate to intellectual development, problem-solving, motivation, cognition, and identity (Danielak et al., 2014; Faber & Benson, 2017; Felder & Brent, 2004; King & Magun-Jackson, 2009; McNeill et al., 2016). Significant findings indicate that personal epistemologies are nuanced and complex (Montfort et al., 2014), closely tied to identity (Danielak et al., 2014; Montfort et al., 2014), and are deeply contextual (e.g., school versus the "real" world) (Beddoes et al., 2017a; Faber & Benson, 2017; McNeill et al., 2016).

Although not specific to practicing engineers, Monfort et al. (2014) explored the personal epistemologies of civil engineering faculty, providing a unique example of personal epistemology research not in the context of student learning or development, but rather as empirical evidence to contribute to larger discussions of engineering epistemology. Finally, Beddoes et al. (2017b) argue that it is vital to study the personal epistemologies of practicing engineers because it provides the empirically driven evidence needed to square the beliefs of engineers with philosophical assertions. Ultimately, the beliefs that engineers hold about knowledge and ways of knowing can provide powerful insight into broader cultural beliefs and be used as evidence for critical epistemological discussion regarding what engineering knowledge is or should be.

Epistemic practices

Greater meaning can be made out of engineers' beliefs about knowledge and ways of knowing through an understanding of their epistemic practices (Beddoes et al., 2017a). Thus, in order to further interrogate the epistemic hierarchy of engineering, we must also consider the epistemic practices of engineers and how they relate to the beliefs engineers hold about engineering knowledge and ways of knowing. Indeed, beliefs, knowledge, and practices are inherently bound together within a sociocultural context (i.e., community of practice) (Wenger, 1998).

I operationalize epistemic practices as actions related to knowledge gathering, implementation, justification, or sharing. In this study, I consider an epistemic practice as any action involved in the gathering, implementation, justification, or sharing of engineering knowledge or information (adopted from Beddoes et al., 2017a). Epistemic practices are inherently contextual and are inextricably linked to identity and knowledge (Beddoes et al., 2017a). Exploring epistemic practices is necessary because, within a given field (or community of practice), epistemic outcomes are often dictated by the epistemic activities or practices that are normalized within that community, including how "members of a community propose, justify, evaluate, and legitimize knowledge claims within a disciplinary framework" (Kelly, 2008, p. 98). In other words, epistemic practices are a way in which individuals are socialized into their communities. Similarly, work related to the study of epistemic cultures has shown that within a given field, there are certain arrangements, mechanisms, and practices that makeup how knowledge becomes known (Cetina, 2009). Ultimately, we determine what we know and how we know it through the practices in which we are socialized within a given context or social systems

There is a need for more research into the epistemic practices of practicing engineers. Similar to beliefs about knowledge and ways of knowing, engineering education research on epistemic practices has primarily centered around how epistemic practices can be used to facilitate learning, particularly in pre-college environments. For example, Kelly and Cunningham (2019) argue that providing opportunities for K-12 students to learn and execute epistemic practices related to engineering can develop their identities as learners of engineering and problems solvers. Through their work, they offer 16 epistemic practices of engineering, broken down into four categories: engineering in social contexts, uses of data and evidence to make decisions, tools and strategies for problem-solving, and findings solutions through creativity and innovation (Cunningham & Kelly, 2017). Ultimately, they argue that through the incorporation of epistemic practices of engineering into the pre-college curriculum, students can learn the distinct features of engineering knowledge.

Relatively little research has explored the epistemic practices of professional engineers. As pointed out in a synthesis of research related to professional engineering work, in general, the amount of research on practicing engineers is considerably less when compared to research focused on scientists or engineering students (Stevens et al., 2014). One such study that investigated the epistemic practices of practicing engineers compared them to the practices of students and faculty (Babikoff, 2018). Babikoff (2018) found that the most prevalent epistemic practices varied considerably across groups and that practicing engineers most frequently discussed employing practices related to "producing tangible results, limiting consequences, and reducing uncertainty" (p. 38). Additionally, the study concluded that the epistemic practices employed by the different engineers (students, faculty, practitioners) were relational to their engineering identities.

Finally, several field studies (i.e., ethnographic research designs) of practicing engineers have attempted to describe the unique work practices of engineers within professional contexts (Stevens et al., 2014). A key finding from the synthesis of these field studies of engineering practice was that there is an unrealistic social-technical divide that exists within engineering even though practices often reflect the inextricable nature of the social and technical in engineering (Stevens et al., 2014). The finding that there is an unrealistic yet pervasive social-technical divide in engineering supports my earlier claims (see *Chapter, 2, The Epistemic Hierarchy of Engineering*) and also provides evidence for the need to explore the relationship between cultural beliefs and epistemic practices.

Identity

Greater meaning can be made out of engineers' beliefs about knowledge and ways of knowing when studied alongside their identity (Beddoes et al., 2017a). In order to further interrogate the epistemic hierarchy of engineering, understanding how engineering identity relates to the epistemic hierarchy of engineering is a critical component. Additionally, exploring identity is important to further our understanding of how the epistemic hierarchy of engineering can perpetuate exclusion since researchers have shown that if one does not identify with the epistemic landscape of their engineering environment, they can be made to feel marginalized (Cech et al., 2017; Danielak et al., 2014).

Engineering identity is a multi-faceted and complex research construct. Engineering identity has been theorized in engineering education literature in many different ways (Patrick & Borrego, 2016). Most simply, identity is considered to be beliefs about the self. It is widely acknowledged that self-beliefs don't form in isolation and thus several of the major identity theories, including those employed in engineering education research, conceptualize identity in relation to socialization and context, such as multiple identity theory, social identity theory, and sociocultural theory (Patrick & Borrego, 2016).

Multiple identity theories are perhaps the most popular in engineering education identity research as two of the most popular frameworks are multiple identity frameworks. First, the work of James Paul Gee is often used as an analytical lens to study identity. Gee's identity framework states that people have multiple identities all connected to their performances in society and shaped by their experiences (Gee, 2000). Gee conceptualizes identity as acting and interacting as a certain "kind of person" considering four perspectives on identity that all interrelate in complex ways; nature (i.e., a state), institution (i.e., a position), discourse (i.e., a trait), and affinity (i.e., an experience*)*. In this analytical lens, aspects of an engineering identity could be associated with all four perspectives. These perspectives are used to help interpret self-perceptions based on the beliefs and experiences of the individual.

Another multiple identity theory used in engineering education research is to conceptualize engineering identity as a specific role identity that interplays with the individual's personal identities and social identities (Burke et al., 2003). In this context, a role identity (i.e., engineer) is the meaning the individual applies to a social or cultural role. Popular within engineering education research is the framework by Hazari et al., (2010) that was then further built upon by Godwin et al, (2016), which operationalizes engineering identity as a role consisting of three major components; 1) recognition by others, 2) interest in the subject matter, and 3) beliefs about performance and competency (Godwin et al., 2016; Hazari et al., 2010). In general, multiple identity frameworks are useful because they take into account the complex multiple identities that we all have and consider how certain aspects of our identity are more salient within certain contexts and environments.

Similarly, social identity theory considers identity within social contexts but further posits that a person's sense of self is based largely on their group membership(s). Social identity theory seeks to understand intergroup behavior through social identity

(Tajfel & Turner, 1978). Social identity theory attempts to address three main issues in terms of how individuals identify with groups and thus theoretically frames social identity through; 1) psychological processes that explain a person's social identity (e.g., social categorization, social comparison), 2) strategies people use to derive social identity (e.g., social competition) and 3) characteristics of the social structure that determine which strategies are likely to be used (Ellemers & Haslam, 2012). Social identity theory is used across academic disciplines and has helped researchers understand group processes and intergroup relations.

I operationalize engineering identity to include considerations for sociocultural context and social forces. In this research, I combine several identity theories to operationalize engineering identity as a role identity (Burke et al., 2003) that is negotiated within a sociocultural context, such as a community of practice (Wenger, 1998) and can have different meanings, interpretations, or salience based on aspects of one's social identity (e.g., gender or race). This operationalization is important because it aligns with the theory of community of practice (Lave & Wenger, 1991) and sociocultural theory viewing identity as negotiated through social processes of learned cultural values, beliefs, and practices (Vygotsky, 1978). Indeed, Wenger (1998) argues that "the formation of a community of practice is also the negotiation of identities" (p. 149). Thus, identity development within a community of practice is central to understanding how beliefs and practices are bound together within a sociocultural context.

There is a need for more research on the engineering identity of practicing engineers. Engineering identity research has grown in popularity in higher education in recent years, primarily investigating the relationship between identity development and retention, academic outcomes, and the impact of interventions in higher education settings (Patrick & Borrego, 2016). However, research related to the identity of practicing engineers is sparse. A recent systematic review of empirical studies of practicing engineers found approximately 12 studies (published between 2000-2018) related to professional engineering identity (Mazzurco et al., 2020). Additionally, the systematic review found that only a few studies considered the influence of other aspects of one's identities (e.g., personal identity, social identity) on their engineering identity. As such, there is much work to be done in this space.

One study conducted with practicing engineers that I found particularly relevant to this research was an ethnographic study conducted by Faulkner (2007) exploring how the boundary between the "technical" and the "social" is drawn within engineering identities, specifically considering the influence of gender in this boundary drawing. Faulkner found that engineers tend to cling to the "technicist" engineering identity even as they move into more managerial roles as it gives them a sense that they are still "real" engineers. Further, she found "that technicist engineering identities persist in part because they converge with (and perform) available masculinities" (p. 331) and as such, women's membership as "real" engineers are more fragile, particularly when they move out of more technical roles. This study provides further evidence for the importance of exploring the relationship between engineering identity, epistemic hierarchies, and socially constructed gendered norms.

Gender and race are social structures that shape identity. The social structures of gender and race are powerful forces in society and shape identity (Tefera et al., 2018). In this research, I follow feminist theory to define gender as "the structure of social relations that centers on the reproductive arena, and the set of practices that bring reproduction between bodies into social processes" (Connell, 2009, p. 11). In other words, I do not consider gender as a pre-determined, fixed, binary, or biological feature, but rather a social structure constructed out of expectations of behaviors placed on certain bodies. Connell (2009) further articulates the complexity of gender is that "it is not just about identity, or just about work, or just about power, or just about sexuality, but all these things at once" (p. 11). Similarly, I define race as not a biological or natural feature, but as a socially constructed category created to systematically exploit and oppress certain groups of people (Biewen & Kumanyika, 2017). Additionally, intersectional aspects of an engineer's social identities are imperative to understanding their participation within the community of practice because an individual's ability to influence and operate within social systems (e.g., a community of practice) is dependent on many factors including various aspects of social identities (Harding, 1991) and power relations are, of course, deeply intertwined with constructions of social identity (Collins & Bilge, 2016).

In this research, I consider gender and race as key aspects of social identity The social structure of gender is a central consideration because of my feminist perspective and because of the gendered ways that engineering knowledge and ways of knowing have been constructed in engineering (Faulkner, 2007). The social structure of race is also explicitly considered because 1) I understand that gender interacts with other forms of social relations, particularly race (Sprague, 2016) and 2) the racially oppressive way that smartness and intelligence are constructed (Carroll et al., 2019; Gutiérrez y Muhs et al., 2012; Hatt, 2016; Leonardo & Broderick, 2011), which are deeply relational to ways of knowing in engineering.

Communities of practice

The theory of community of practice (CoP) is used in this research to contextually frame the beliefs, practices, and identities of practicing engineers. According to Beddoes et al. (2017a), accounting for context is vital to making sense of the complex beliefs that engineers hold about knowledge and ways of knowing. A CoP is essentially a learning and knowledge-sharing community, where meaning is made through the interconnected relationship between knowledge, practices, and identity (Lave & Wenger, 1991; Wenger, 1998). Indeed, a CoP bounds knowledge, practices, and identity together (Lave & Wenger, 1991). As Beddoes et al.(2017a) argue, the "significance of communities of practice lies in the ways it highlights the central influential role that everyday practices play in shaping knowledge, identity, and learning" (p.76). Given that my research interest is knowledge hierarchies and the beliefs and practices that support and reproduce those hierarchies, a community of practice is a conceptually compatible framework.

The theory of CoP evolved out of the work of Vygotsky and sociocultural theory (Vygotsky, 1978), meaning that it originated as a situated learning model for exploring how beliefs and meanings are negotiated through social and cultural practices (Benzie et al., 2005). Although the CoP framework is rooted in situated learning theory, Wegner (1998) is clear that it can inform more than just academic spaces and that the framework is of value to professional organizations and communities. As such in this work, I conceptualize a structural engineering consulting firm as the community of practice (discussed in more detail in *Chapter 3, Context and Community of Practice*), which provides a shared sociocultural context to explore the beliefs, reported practices, and identities related to engineering knowledge of ways of knowing of practicing engineers

Chapter 3. Methods

In this chapter, I provide a detailed explanation of the qualitative methods employed in this research. First, I provide an overview of my worldview as a researcher as well as how my positionality influences this work. I then provide a detailed discussion of the research context, participant recruitment and selection, data collection, data analysis, and how quality was considered throughout the research.

Researcher Worldview

In any research project, attention and alignment must be paid to the epistemological, theoretical, and methodological approach to the research (Jones et al., 2013). In this study, I take an interpretive qualitative approach to explore how the beliefs about engineering knowledge and ways of knowing, reported epistemic practices, and identities of practicing engineers justify (or resist) the epistemic hierarchy of engineering. Table 3 provides an overview of my worldview as researcher and my approach to this study, which will be discussed in detail in the following sections.

Table 3: Researcher Worldview

Research Paradigm	Interpretive
Theoretical Perspective	Feminist Perspective
Research Theoretical Framework	Communities of practice (meaning making through shared beliefs, identity, and practices), the epistemic hierarchy of engineering
Research Methods	Semi-structured, one-on-one interviews with graphic elicitation; Inductive coding, analytic memos, data display and theme development

Interpretive qualitative research

Interpretivism is the overarching research paradigm of this study. Interpretivists seek to understand the world through the subjective experiences of individuals and their interactions with others (Creswell & Poth, 2018). Interpretivists reject the idea that there is a single "objective" truth but rather adhere to the idea that meaning is constructed through interactions and negotiated in a social context (Jones et al., 2013). Interpretivism is well suited for this study as I aim to explore how engineers subjectively make sense of their day-to-day experiences (i.e., epistemic practices) and the social interactions within their social context (i.e., community of practice), all of which inform their beliefs and identities as engineers (Wenger, 1998).

Feminist perspective

I approach this study from a feminist theoretical perspective. To be clear, there is not a single approach to feminist research. Indeed, feminists disagree on many issues in research with differing methodological perspectives (Sprague, 2016). However, there is consensus amongst feminist perspectives that "gender in interaction with other forms of social relations such as race/ethnicity, class, and nation is a key organizer of social life; and that understanding how things work is not enough - we need to take action to make the social world more equitable" (Sprague, 2016, p. 3). Thus, the goal of this research is to interrogate the epistemic hierarchy of engineering that has perpetuated exclusion and ultimately, contributed to gender inequity in engineering. Through my feminism, I approach this research with an understanding that the knowledge generated from this study is not value-free (Harding, 1991). My intention with this work is to aid in imagining a more socially conscious and inclusive engineering field by disrupting the epistemic hierarchies of engineering that are limited and perpetuate exclusion.

Specifically, I bring my feminism into this research in two ways; 1) interrogating the epistemic hierarchies of engineering that have contributed to gender inequity is in itself an act of feminism, and 2) incorporating feminist strategies into the methods utilized in this research through an understanding that knowledge and access to knowledge are socially situated. First, drawing on feminist science and technology scholars, Riley et al. (2009) argues that interrogating the (hidden) assumptions within the profession of engineering (e.g., the assumptions that reproduce the epistemic hierarchy of engineering) is a way to incorporate feminism into engineering education research. Further, the way that masculinity is associated with the "technical" and femininity with the "social" has been shown to result in more fragile engineer identities for women (Faulkner, 2007). Thus, by further interrogating the ways in which engineers relate their identity (engineering identity and social identities) to the epistemic hierarchy of hierarchy, we can continue to understand how the epistemic hierarchy of engineering contributes to gender inequity.

Second, I bring my feminism into this research by incorporating feminist strategies throughout the methods. Sprague (2016) states that "what distinguishes critical from uncritical research is not the methods used but *how* the method is used both technically and politically" (p. 30). From my feminist perspective, I approach the methods with an understanding that knowledge and the knower's access to knowledge are socially situated and constructed relative to power rooted in social relations (Sprague, 2016). Thus, throughout my data collection and analysis, the social structure of gender along with its interaction with other forms of social relations is considered. Specific examples of how I incorporated my feminist perspective into the methods will be provided throughout this chapter.

Positionality

Researcher positionality greatly impacts any research study and is a fundamental aspect of the research topic, epistemology, ontology, methodology, researcher's relation to participants, and communication (Secules et al., 2021). Therefore, it is imperative in quality research that the researcher includes a positionality statement in which they reflect upon how their positionality motivates the project and how they situate themselves within the project (Jones et al., 2013). I identify as a White cisgender woman who is a researcher, an educator, and a structural engineer. My motivation to study knowledge and ways of knowing in engineering is due, in large part, to my own experiences in engineering school and practice. Having been socialized to consider engineering ways of knowing as purely objective, rational, and emotionless, I struggled throughout my professional career and found myself dissociating aspects of my social identity and values from my engineering work in order to maintain a sense of belonging in engineering. Additionally, I struggled with how to deal with ambiguity in the engineering design process, which I felt was at odds with what I learned during my educational experiences. When I started my Ph.D. program and began to learn about epistemology and ontology in my research methodology courses, I was blown away. It was the first time I had been exposed to other ways of knowing and thinking within my formal education. As I continued my Ph.D. journey, including the courses I took through the Women's, Gender, and Sexuality Studies Department here at Ohio State, I further came to the realization that the lack of understanding and validation of other ways of thinking and knowing is a serious problem in engineering--a problem made even worse by pervasive cultural assumptions that engineers are "smarter" than others. It is my understanding that assumptions of intellectual superiority and the ideologies associated with dominant ways of knowing in engineering (e.g., objectivism, individualism, depoliticization) underpin many of the social justice issues that we face in engineering. As Cech (2013) argues, the social-technical divide in engineering that supports the ideology of depoliticization frames social justice issues as irrelevant to engineering practice. Continued reflection on how my positionality influences my relationship with the participants as well as how I collect and analyze the data can be found in the respected sections of this Chapter.

Context and Community of Practice

The context of this research centers around a professional structural engineering community of practice. As described in Chapter 2, a community of practice is a learning and knowledge sharing community (Wenger, 1998) where meaning is made through the interconnected relationship between knowledge, practices, and identity (Lave & Wenger, 1991). For this work, I conceptualized a structural engineering consulting firm as the community of practice. A structural engineering firm can be considered a community of practice because it has the three key characteristics of a community of practice; 1) a shared domain (e.g., structural engineering), 2) a community (e.g., a shared working environment), and 3) a practice (e.g., completing engineering projects) (Wenger, 2011). Additionally, as engineers get hired into the structural engineering consulting firm, they must learn the values of the company and take part in the social practices of that firm, which is also essential when joining a community of practice (Wenger, 1998). Further, the engineers at the structural engineering firm are all part of the shared enterprise of the community and negotiate their identities within that community of practice. The structural engineering firm at the center of this research will be henceforth referred to as the Firm.

The Firm is a mid-sized company with approximately 80 employees (55 structural engineers) across three offices. The Firm was founded in the mid-1970s in a Midwestern city. The firm specializes in structural engineering consulting with projects ranging from commercial, residential, light industrial, to entertainment. The core of the Firm's business and largest client base comes from architectural firms. The Firm is very structured in terms of leadership with a clear division between design engineers, project engineers, project managers, and then the Firm's leadership and management team. The firm highly values collaboration and markets itself as being more approachable and creative than other structural engineering firms.

I chose this specific community of practice because I worked as a structural engineer at a company very similar to the Firm prior to pursuing my Ph.D., which uniquely positions me to have personal insight and understanding of the epistemic practices and real-world context of the community of practice. Beddoes et al.(2017a) argue that it is central for the researcher to have a nuanced understanding of real-world context to be able to communicate and more accurately understand the participants, particularly when investigating beliefs about knowledge and ways of knowing. Also, given my professional relationship with several members of the leadership team at the Firm, I was able to gain access to the engineers at the Firm.

Finally, to be clear, I wanted to perform research in the context of engineering practice for two key reasons. First, in the field of engineering education, more research is needed that centers on the context of engineering practice, which can help bridge the gap between school and practice (Stevens et al., 2014). Additionally, in the spirit of feminist science and technology scholars, research in the context of engineering practice provides an opportunity to uncover (hidden) assumptions within the profession which is needed to critically reflect on professional engineering culture (Riley et al., 2009). Through a critical examination of professional engineering culture, educators can help develop students (and professionals) to be change agents if they choose to be.

Recruitment and Selection of Participants

In accordance with the Institutional Review Board (IRB) approved protocol (Study ID # 2021E0539), I recruited participants from the Firm using a recruitment email that informed the participants about the study and included a link to an online survey to complete if they were interested in participating. The email was forwarded to the structural engineers at the Firm by two members of the leadership team who agreed to help me recruit participants. The recruitment survey (refer to Appendix A) consisted of demographic questions including gender, race, ethnicity, and years of structural engineering experience. From my feminist perspective, I did not want to make any assumptions regarding the participant's gender or racial identity. As such, I provided the opportunity to the participants to self-identify their gender and race or to choose not to identify. Also, I provided an option to "prefer to self-describe" gender with a write-in box as to not limit the engineer's gender identity to the provided gender categories (i.e., man, women, non-binary). The survey also contained two short, open-ended questions to get preliminary insight into their professional background and their understanding of what it means to think like an engineer:

- In 1-2 sentences, please briefly describe your professional background and career trajectory (e.g., what type of projects do you typically work on?, What kind of role are you currently in?)
- In 1-2 sentences, please describe what it means to think like an engineer.

The survey was distributed using the university-approved online survey platform, Qualtrics. Additionally, in accordance with the IRB protocol, the consent form was included in the survey so while filling out the survey, the engineers consented (or not) to being part of the study.

I selected participants using a purposeful sampling approach. The sample was purposeful in that it consisted of structural engineers from the community of practice that could provide information-rich data and insight into the research questions (Jones et al., 2013). Ultimately, 10 engineers from the community of practice responded to the recruitment survey and all 10 were selected as they all met the expectations of the purposeful sampling approach. Selection meant that they were invited to participate in a semi-structured interview (details provided in the next section).

The 10 participants equated to approximately 20% of the structural engineers at the Firm. Table 4 provides each participant's self-identified gender and race along with their self-selected pseudonyms. Given the limited number of engineers at the Firm, I felt that providing more details (e.g., years of experience, position in the Firm) would make the participants too identifiable. Additionally, given the lack of racial diversity at the Firm, I felt that providing the specificity of their self-identified race and ethnicity would also make them too identifiable. As such, I have combined self-identified ethnic and racial identity categories into either dominant in terms of the racial and ethnic make-up of engineering (White and non-Hispanic) and non-dominant (Hispanic or Black/African-American or Asian or American Indian/Alaska Native or Native Hawaiian/Pacific Islander). To be clear, I do not mean to take away or erase the participant's identification to a specific ethnic, or racial group, but I felt it was ethically important to prioritize the anonymity of the participants.

Table 4: Participants

Participant	Gender	Ethnicity/Race
Alex	Non-binary	Dominant
Andreas	Man	Non-dominant
Dan	Man	Dominant
Erica	Woman	Non-dominant
Jake	Man	Dominant
Julia	Woman	Dominant
Lisa	Woman	Dominant
Martin	Man	Dominant
Nichole	Woman	Dominant
Yolanda	Woman	Dominant

In general, I tried to sample across demographics because as Harding (1991) argues, an individual’s ability to influence and operate within social systems is dependent on many factors including various aspects of social identities. There is much insight to be gained about how social systems function from the perspectives and beliefs of individuals from varying positions within that social system.

Ultimately, the sample consisted of five engineers who self-identified as women, one who self-identified as gender non-binary, and four who self-identified as men. No other self-identified gender categories were listed on the recruitment survey. Publicly available information on the Firm’s website at the time of recruitment indicated that around 25% of the engineers at the Firm were women, meaning that women were oversampled in this study. This was intentional given my feminist perspective and my interest in exploring how the social structure of gender relates to how the engineers identify with the epistemic hierarchy of engineering. Oversampling women allowed me to explore the identity and experiences of those who identify as women at the Firm.

Additionally, the sample is predominately White and non-Hispanic, which is reflective of the racial and ethnic makeup of the Firm. Although there was no public information available regarding the racial or ethnic makeup of the engineers at the Firm; from my discussion with a member of the Firm's leadership team prior to recruitment, there is very little racial and ethnic diversity at the Firm. The predominately White and non-Hispanic sample is useful in investigating the dominant shared beliefs of the community of practice. However, it is certainly a limitation of the study as it limits my ability to explore the racialized implications of the epistemic hierarchy in engineering as well as the beliefs, practices, and identities of those at the intersection of oppressed social identity categories (i.e., women of color).

Finally, it should be noted that I was prepared to recruit more participants if necessary and had planned to ask my contacts at the Firm to send out the recruitment email again if more participants were needed. However, given the consistency in the responses from the 10 participants, I felt as though I was able to reach saturation of the analytical themes. I determined saturation during the preliminary data analysis as it was clear that I was getting similar responses from the participants to the interview questions (Jones et al., 2013). Overall, I found that the quality of the data from the 10 participants was sufficient to answer my research questions.

Data Collection

Interview protocol development and graphic elicitation

I used semi-structured, one-on-one interviews as the primary data collection method for this study, which is a common data collection method used in interpretive and feminist research (Jones et al., 2013; Sprague, 2016). The semi-structured interview protocol included questions related to the constructs of interest per the conceptual framework (i.e., beliefs about engineering knowledge and ways of knowing, epistemic practices, and identity). The interview protocol (refer to Appendix B) questions were adapted from similar studies related to personal epistemology (Beddoes et al., 2017a, 2017b; Montfort et al., 2014), epistemic practices (Babikoff, 2018), and engineering identity (Kramer et al., 2020).

The interview protocol also included a graphic elicitation exercise. Graphic elicitation is a type of visual elicitation method, which is common in qualitative research as it can provide added stimuli for participants and can "evoke deeper elements of human consciousness" than words alone (Harper, 2002, p. 13). In other words, it provides another means to elicit meaning, emotions, and understanding during the interview process. Within engineering education, visual elicitation methods such as photo-elicitation and the "draw an engineer test" have been successfully implemented (e.g., Knight & Cunningham, 2004; Morley et al., 2011). Graphic elicitation, specifically, involves asking the participants to provide visual data to represent their personal understanding of concepts or beliefs and in conjunction with semi-structured interviews, can enable participants to express complex ideas or opinions (Copeland & Agosto, 2012; Crilly et al., 2006).

Since I approach this research with a theoretical understanding that the epistemic hierarchy of engineering is “baked” into engineering communities of practice, incorporating the graphic was the way in which the epistemic hierarchy of engineering was made explicit in the interviews. I did this by providing the participant with items that are related to types of knowledge and ways of knowing in engineering based on the extant literature discussed in Chapter 2. Table 5 provides a list of the types of knowledge and ways of thinking used in the graphic elicitation.

Table 5: Types of Knowledge and Ways of Knowing used for Graphic Elicitation

Types of knowledge in engineering	**Primary source**
Math and science knowledge	Cech, 2014; Pawley, 2009
Project management knowledge	Added after pilot interviews
Ethical knowledge	Cech, 2014
Writing and communication knowledge	Cech, 2014
Social knowledge	Cech, 2014
Political knowledge	Cech, 2014
Other (write-in)	
Ways of knowing engineering	**Primary source**
Analytical / rational thinking	Sternberg, 1985; Guanes et al.2019
Creative thinking	Sternberg, 1985
Practical thinking	Sternberg, 1985
Intuitive thinking	Guanes et al. 2019
Empathy / emotional thinking	Guanes et al. 2019
Other (write-in)	

In creating items for the list of types of knowledge in engineering, I drew primarily on Cech’s (2014) work on the culture of disengagement in engineering, where she had participants place importance on items such as math and science, writing and communication, ethics and social issues. I also included project management knowledge after my pilot interviews (discussed in more detail in the following section) because there was significant discussion from my pilot participants regarding the importance of project management knowledge in engineering, specifically knowledge needed to manage project schedules and budgets.

In creating items for the list of ways of knowing in engineering, I drew on the framework developed by Guanes et al. (2019), which considered types of reasoning used in engineering decision making and consisted of rational, empathic, and intuitive thinking. I also drew on Sternberg's (1985) triarchic theory of intelligence, which included a framework for conceptualizing intelligence as creative, analytical, and practical thinking. Including the ways of knowing associated with the two frameworks ensured that I incorporated multiple ways of knowing in engineering. It also ensured that I included considerations for empathy and creativity, which have been the subject of extant engineering education research highlighting their importance (For example, Daly et al., 2014; Hess & Fila, 2016; Walther et al., 2017). Finally, I added a write-in option so that participants could add anything else that they deemed as an important type of knowledge or ways of knowing in engineering. It should be noted that the items listed were not intended to be the definitive list of types of knowledge and ways of knowing in engineering but rather a tool used to help generate discussion during the interviews.

I asked the participants to graph each item based on what is most important to them personally and based on what they believe other structural engineers would consider most important within the context of structural engineering. Refer to Figure 3 for the template of the graphic elicitation exercise.

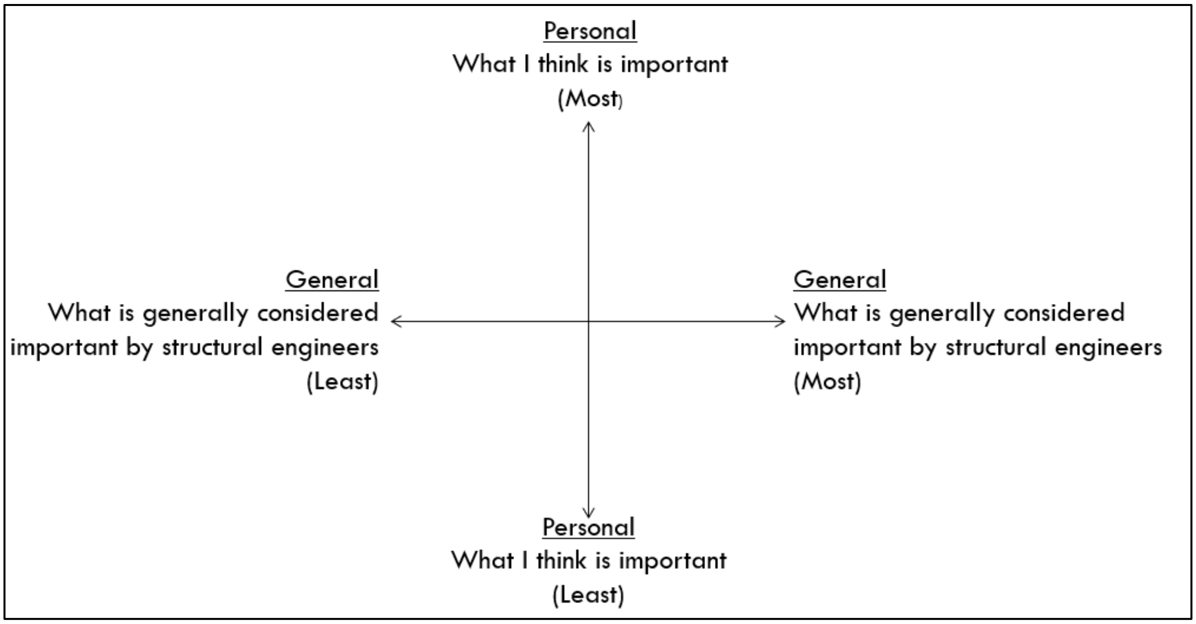

Figure 3: Graphic Elicitation Exercise Template

During the graphic elicitation exercise, I asked follow-up questions to better understand how the participants justified their graphs. The follow-up questions were also intended to unpack any misalignment between their personal beliefs and what they perceive to be important in the profession. Refer to Appendix B for the interview protocol

Pilot interviews and interview protocol refinement

I piloted the interview protocol with two practicing structural engineers who were former employees of the Firm but had since moved on to other career opportunities. The pilot participants were selected based on their familiarity with the community of practice. In accordance with the IRB approved protocol, the pilot participants were recruited through my professional network via email. The purpose of the pilot was to ensure that the interview questions elicited responses from the participants that would enable me to answer the research questions. After the pilot interviews, I used an interview protocol refinement tool that I helped develop during a prior study that was designed for refining interview protocols investigating complex constructs such as beliefs and identity (Kramer et al., 2020). Specifically, I summarized how I would answer each research question for each pilot participant to help verify that the questions I was asking would provide data that could indeed answer my research questions. I also went through each interview question to determine if any caused confusion, needed to be re-worded, or removed.

Overall, I found that the interview questions initiated responses from the pilot participants that provided quality data and would allow me to answer my research questions. During the pilot interview, I found the graphic elicitation exercise was particularly useful. As previously mentioned, I did add “project management knowledge” to the exercise given how much both of my pilot participants talked about the role of project management knowledge in their day-to-day engineering work. Additionally, I found that I needed to add more follow-up questions related to epistemic practices during the graphic elicitation exercise (e.g., please provide a specific example of using this in practice). Finally, I found that there was some confusion regarding what was meant by “social knowledge” and “political knowledge.” For example, both pilot participants asked me to distinguish between office politics and national politics. However, I decided not to edit the items of “social knowledge” and “political knowledge” during the graphing activity because I found it interesting to see how the participants reacted to their inclusion on the list and to get the participant’s initial interpretation of the item. I did, however, prepare a standard follow-up question asking participants to explain how they felt knowledge of social or political issues such as sustainable design practices, considerations for community impact of their structures, and the role of diversity, equity, and inclusion initiatives in engineering related their work.

Semi-structured interviews

I conducted the semi-structed, one-on-one interviews over the video communication platform Zoom. Conducing the interviews over Zoom allowed for flexibility in scheduling and allowed me to interview participants from the different offices of the Firm. I audio recorded the interviews (no video was recorded) and I collected the completed graphs from the graphic elicitation exercise in a PDF form. All interviews lasted approximately 60-90 minutes. Prior to the start of the interviews, I reviewed the informed consent process with each participant and provided them with information regarding what to expect during the interview. Also, before each interview, I asked the participants to self-select a pseudonym.

After all of the interviews were complete, I employed a form of member checking (Jones et al., 2013) by sending a copy of the cleaned transcript to the participant. During the member checking process, I asked the participants to review their cleaned transcript for accuracy and gave them the opportunity to provide additional insight regarding the interview topics. Asking the engineers to provide additional insight also served as a form of data collection (Jones et al., 2013). The member checking procedure will be discussed in more detail in the Quality section of this Chapter.

Incorporating a feminist perspective into data collection

Interviewing can be a powerful tool for feminist researchers. As a method, it provides space for people to share their truths and is a way to understand the situated experiences of individuals (Sprague, 2016). However, there are still important issues that feminist researchers must navigate while conducting interviews. I considered two main issues while conducting the interviews to ensure that I approached the data collection from a feminist perspective; 1) the salience of gender, race, and class in the research relationship and 2) the potential objectification of the research subjects (Sprague, 2016).

In this research, I had to navigate the power dynamics between myself as a White woman and the various positionalities of the participants. This, of course, impacted how I related to the participants of the study and the data they provided. There were different power dynamics at play while interviewing the White men holding positions of power versus interviewing the woman of color. For example, when interviewing Erica (woman holding non-dominant racial/ethnic identity), I tried to employ an additional level of care. Erica shared with me a story in which she was treated differently during an internship experience than her While-male counterpart. I tried to lead with empathy by sharing a similar experience that I had during my professional career, but also being clear that I understood that my experience as a White woman in engineering was different than hers. Additionally, I tried to maintain awareness of how I navigated hegemonic discourses throughout the interviews. For example, many of the participants spoke about the role of objectivity in engineering and how they shouldn't be making decisions based on emotion or their political views. I tried to provide space for the participants to express their beliefs but also tried to lightly push back during follow-up questions. Specifically, I tried to highlight the subjectivity of some of their decisions and connect them to the sociopolitical impact that their design have on the environment and the community.

Additionally, in this research, I tried to avoid “othering” the participants during the research experience. Sprague (2016) warns that during interviews, participants can be the object of the researcher’s manipulation. I tried to alleviate the sense of othering during the interview by breaking down the dichotomy between researcher and researched. Specifically, I tried to be as transparent as possible with my participants and leverage my experience as a professional engineer as a bridge between myself and the participants.

Data Analysis

The interviews were transcribed verbatim using the university-approved transcription service Rev.com. I then cleaned and de-identified the interviews prior to any analysis. Cleaning and de-identifying the transcripts included checking the transcripts for accuracy and removing any identifiable information (e.g., name of university attended, prior employers). The data analysis consisted of a systematic yet emergent and inductive process consisting of:

- Data condensation around the main constructs of interest (i.e., beliefs about engineering knowledge and ways of knowing, epistemic practices, and identity) using inductive coding techniques (values and process coding),
- the development, refinement, and application of a codebook,
- detailed analytic identity memos,

- a simplistic analysis of the graphic elicitation exercise, and
- iterative and interpretive theme development

Refer to Figure 4 for a visual overview of the data analysis process. In the following sections, each step in the data analysis process will be discussed in detail.

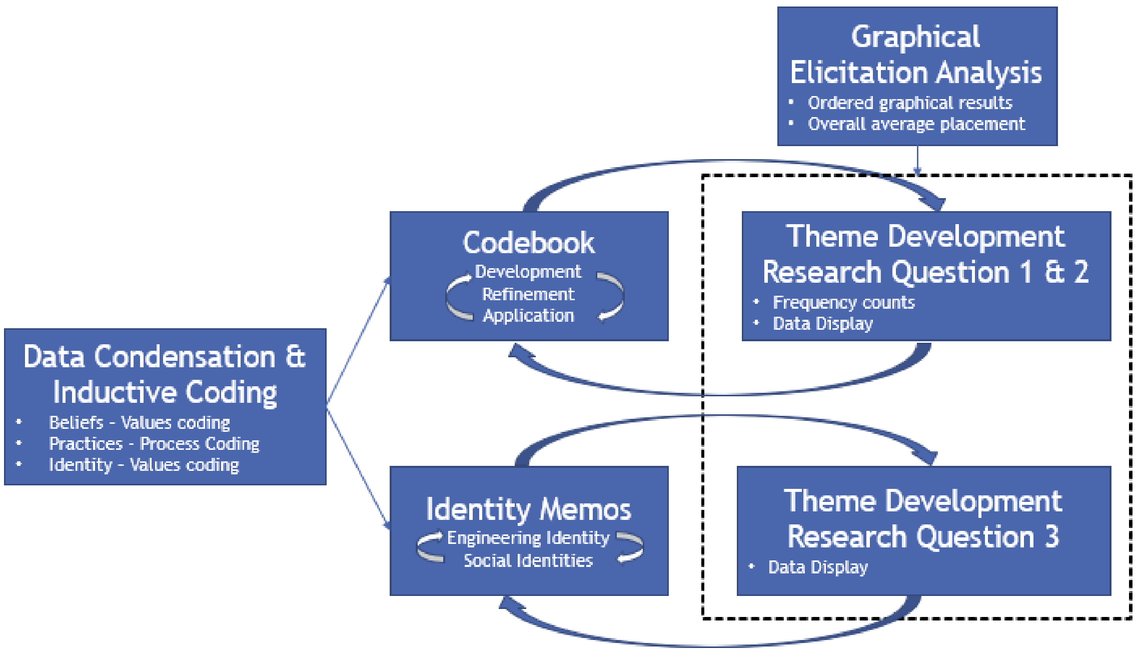

Figure 4: Overview of Data Analysis Procedures

Data condensation and inductive coding

I began the data analysis using a systematic coding approach condensing the data around the constructs of the conceptual framework (i.e., beliefs about engineering knowledge and ways of knowing, epistemic practices, and identity). Data condensation is the process of "selecting, focusing, simplifying, abstracting and/or transforming the full corpus (of data)" and by doing so, making the data "stronger" (Miles et al., 2018, p. 8). Due to the nature of the semi-structured interviews questions, participants often discussed a variety of aspects of their professional experiences, so condensing the data around the main constructs of interest was important in keeping the analysis aligned with the goals of the research, the research questions, and the conceptual framework.

To consider the beliefs and identities of the participants, I implemented values coding. Values coding is the application of codes to data reflective of the participant's attitudes, values, and beliefs (Miles et al., 2018). Values coding is appropriate for this research because it is useful in studies involving cultural values and beliefs, identity, and interpersonal experiences (Miles et al., 2018). This process was guided by asking myself questions such as, *"for this participant, what do they believe count as knowledge or ways of knowing in their engineering work? What do they believe about why certain types of knowledge and ways of knowing are considered more valuable than others? and How does that relate to their identity?"*

It should be reiterated that beliefs are complex constructs that are dynamic, nuanced, and contextual (Pajares, 1992). Although the development of the interview protocol was informed by the framework for personal epistemologies (i.e., beliefs about knowledge and ways of knowing) offered by Hofer and Pintrich (1997), I did not limit the data analysis of beliefs to just elements of the framework (i.e., source of knowledge, justification for knowledge, simplicity of knowledge, certainty of knowledge, sociality of knowledge). Guided by Beddoes et al. (2017a), who struggled to find themes, patterns and make claims regarding the personal epistemologies of their participants within the confines of existing personal epistemology frameworks, I chose to include any espoused belief I found to be related to types of knowledge or ways of knowing in engineering during the initial coding

To capture the epistemic practices of the participants, I also did a coding pass using process coding. Process coding involves the application of codes using gerunds ("ing" words) to identify observable or conceptual actions (Miles et al., 2018). Process coding is appropriate for extracting the participant's reported actions from the data. As such, I considered any action that was related to their epistemic practices. This was guided by asking myself questions such as, *"Is this participant describing an action that involves knowledge gathering, implementation, justification, or sharing?"* Table 6 provides examples of the type of codes developed during the initial coding pass as well as sample quotes for each component of the conceptual framework.

Table 6: Example Codes

Construct	**Type of coding**	**Example Code**	**Example Quote**
Belief	Values Coding	B: engineers are practical	*"When we'd go to these architecture schools, you wouldn't really see buildings. You'd just see abstract forms and stuff that's not really practical, which obviously as an engineer, we're all about practicality"* - Jake
Practice	Process coding	P: Making design decision through collaborative experiences	*"It's usually more in that collaboration that takes place between an architect and an engineer and a mechanical engineer…I think part of it [design decisions] is recognizing and then understanding the other players needs are and then making sure they also understanding what's happening with out needs and our challenges"* - Dan
Identity	Values Coding	I: I am rational/analytic	*"I'm not a super creative person, but I think other people are…I think more of a kind of rational way, analytical, not really looking at the creative aspect of it".* - Erica

Codebook development

After the initial coding of the transcripts using values coding and process coding, pattern coding was implemented to continue to condense the initial codes into a smaller number of concepts (Miles et al., 2018). After initially coding five of the 10 interviews using values and process coding, I began to compile the codes and sought patterns around similar concepts to refine the codes used to capture the beliefs, practices, and identities of the participants. I also begin to develop categories based on similar concepts that I used to group the codes. Due to the complexities of the individual accounts of identity, I decided to separate the analysis procedures for research questions 1 and 2 (*What are the shared beliefs that engineers within a structural engineering community of practice use to justify (or resist) the epistemic hierarchy of engineering?* and *How do the self-reported epistemic practices of engineers within a structural engineering community of practice relate to those shared beliefs?)* and research question 3 (*How do engineers within a structural engineering community of practice relate their engineering identity to the epistemic hierarchy of engineering).* Thus, the codebook was developed around the participants' beliefs and self-reported epistemic practices related to types of knowledge and ways of knowing in engineering.

Once the initial codebook was developed, I then applied the codebook to the remaining five transcripts, iterating throughout the process constantly comparing the data to the codes and categories developed (Jones et al., 2013). While developing the codes and categories, I also added several subcodes to help track some of the nuances of the individual codes. For example,

- Code: Structural engineering design requires collaboration
    - Subcode 1: collaboration with other engineers
    - Subcode 2: collaboration with architects/clients

Additionally, I also added subcodes to help keep track of participants that disagreed with a code. Specifically, I included an "anti" subcode for several codes where there was evidence of contradicting beliefs amongst the participants. For example,

- Code: Politics and emotion should not impact engineering decisions
    - Subcode: Anti: politics and emotion should impact engineering decisions.

Once the codebook was fully developed, I applied the codebook to each transcript using the software Dedoose. Refer to Appendix C for the final codebook developed to answer research questions 1 and 2.

Detailed identity memos

Given the complexity surrounding the participants' engineering identity and relationship with their intersectional social identities, I found it useful to create detailed analytic memos for each participant specifically focused on their identity. I did this because I felt that my initial coding and codebook was not capturing the complexities of the participant's identity. The analytic memos then became the way in which I could more comprehensively but still succinctly make sense of the participant's identities. Generally speaking, analytic memos are common in qualitative research as they are a crucial method for elaborating on data analysis categories, defining relationships in the data, and identifying gaps in the data (Jones et al., 2013). Analytic memos are useful because they not only summarize data but also make analytic meaning (Miles et al., 2018). For this study, I constructed analytic memos for each participant that condensed the interview data in a way that summarized the following items:

- How does the participant identity with engineering?
- What types of knowledge and ways of knowing does the participant identify with the most?
- How does the participant distinguish themselves from other engineers; generally speaking and within their community of practice?
- How do aspects of the participant's social identity (e.g., gender, race) relate to how they see themselves as engineers and their experiences (implicitly and explicitly)?
- How does my positionality relate to how I interpret the data?

The analytic identity memos used in this research were modeled after those described by Pawley (2019) in her study on the ruling relations that structure engineering education. Specifically, she used the memos to reflect on the relationship between the construct of interest in her study (i.e., ruling relations) and the race, class, and gender of the participants. Refer to Appendix C for the analytic identity memo template that I used in this research.

Analysis of graphing exercise

The graphic elicitation exercise was primarily used to generate discussion during the interviews. However, I did conduct a simplistic quantitative analysis of the graphing activity to determine trends in how the participants prioritized the different types of knowledge and ways of knowing in engineering. The intent of the analysis was to 1) confirm my assumptions related to the epistemic hierarchy of engineering within the community of practice and 2) supplement the qualitative findings. The analysis consisted of numerically ordering each item on the graph from one to 11 for each participant based on how they relatively placed each item (one being most important and 11 being least important). I then found the average "ranking" for each item based on all the participants. The purpose of the analysis was to determine the relative order of each item and thus the hierarchy of the items. This process was done twice; once for how the participants relatively placed the items based on what they thought was generally considered important in structural engineering and again for what they individually considered as important in structural engineering.

In order to maintain some sense of how the participants graphically placed each item, I also wanted to be clear about which items were on average placed above or below (or to the left and right) the center axis of the graphs. In other words, I wanted to be clear about which items were on average placed on the half of the graph associated with being most important versus the half of the graph associated with being least important. Therefore, if at least half of the participants graphically placed the item in the least important half of the graph, the item is shown in red text on all associated figures (for example, refer to Figure 5 in Chapter 4).

Data display and theme development

The final step in the analysis process was to develop themes in accordance with the three distinct research questions. To do this, I implemented various data display techniques to establish relationships between the data and ultimately, to develop clear themes grounded in the data. Data display is "an organized, condensed assembly of information that allows analytic reflection and action" (Miles et al., 2018, p. 9).

To develop the findings for research questions 1 and 2, I drew on the results from the application of the codebook on the transcripts in Dedoose. Using the features of Dedoose, I was able to create a data display matrix of the codebook, which included the code applications and frequency for each participant. I then began an iterative process clustering the most frequently applied codes looking for patterns in how the participants either justified or resisted aspects of the epistemic hierarchy of engineering. Considering the patterns in the most frequently applied codes, I was able to develop three major themes for the first research question. Additionally, I was able to align the results of the analysis of the graphic elicitation exercise with the three themes, which provided a visual representation of my findings (Figure 5, Chapter 4). Similarly, for the second research question, I used an iterative data display process to compare patterns of codes related to the beliefs of the participants with the codes related to their reported epistemic practices.

From this process, I developed one major theme for research question 2 (Figure 7, Chapter 4).

To develop findings for the third research question, I drew primarily on the detailed identity analytic memos. Using the memos, I created a data display matrix that mapped the type of knowledge or way of knowing that the participant identified with the most to their self-reported gender and race. Additionally, I created a data display graphic based on my interpretation of the participants' positions within the community of practice. According to Wenger (1998) as engineers move from the peripheral to full membership in the community of practice, they are negotiating their identities within that space. Therefore, I attempted to visually place participants based on how I interpreted their membership within the community of practice ranging from peripheral to full membership. This was largely based on considering their number of years at the Firm, their position within the Firm, and their overall attitude towards the Firm. For example, the participants that I interviewed that held positions of power at the firm were placed closer to the center. I then mapped on the types of knowledge and ways of knowing that each participant identified with the most (Figure 8, Chapter 4). Using the data displays as well as repeated engagement with the analytic memos, I generated one major finding.

Through all analysis procedures, I used a constant comparison approach to ensure all findings are grounded in the data, meaning that I was constantly comparing data with codes, codes with the categories, codes with the data displays, memos with the data displays, and data with the emergent findings (Jones et al., 2013). I also engaged in weekly meetings with my advisor during the data analysis to discuss my findings as well as engaged in peer debriefing throughout the analysis process. This consisted of presenting findings to members of my graduate community and members of the broader research community to get their feedback and input on my interpretation of the data and findings.

Incorporating a feminist perspective into data analysis

I incorporated my feminist perspective into the data analysis by using gender as an analytic lens. This means that throughout the analysis, I did not just consider gender (and race) as clear categories but rather as constructs imbued with socially constructed norms (Pawley, 2017). This aligns with my understanding of gender, which as presented in Chapter 2, I define not as a pre-determined, fixed, binary, or biological feature, but rather a social structure constructed out of expectations of behaviors placed on certain bodies (Connell, 2009).

In the development of the findings for my first and second research question, I explicitly considered gender in the analysis by creating an additional data display matrix that included the frequency counts of codes across self-identified gender categories. Additionally, in the instances where there were trends that showed differences in the beliefs or reported practices of the participants across self-identified gender categories, I asked myself questions like, "*why might certain beliefs or practices be more prevalent in one gender and not others? and How are social relations and power relations influencing the espoused beliefs and practices of those across gender categories?"* These questions helped me interpret the data and are presented as a supplemental finding in Chapter 4. I completed a similar procedure to consider differences across the participants' self-identified race and ethnicity as well.

Considerations for gender were also explicitly incorporated into the creation of the analytic identity memos that were used in answering the third research question. In the memos, I used similar a technique that was applied by Pawley (2019) in her recent work to reflect on the relationship between the race, class, gender of the participants in her study and the ruling relations of engineering education as well as to reflect on how her own race, class, and gender were influencing her interpretation of the data. Additionally, I wrote the memos not just around what the participants explicitly said about race and gender, but I also considered how race and gender may be implicitly functioning in the stories being told by the participants. Including race and gender as an analytical lens was useful in centering the influence of the participants' social identities and social relations on their engineering identity, particularly when considering the socially constructed norms related to ways of knowing in engineering (e.g., masculinity with the "technical" and femininity with the "social'").

Finally, I also incorporated my feminist perspective by carefully considering how my own positionality influences the analysis. As discussed in my positionality statement, I certainly have preconceptions about what I anticipated the participants to say based on my personal experiences working at a structural engineering consulting firm. During the analysis process, drawing on the concept of "strong objectivity," I tried to leverage my own interests, biases, and preconceptions to contribute to the analysis of the data. Strong objectivity was a term first used by feminist philosopher Sandra Harding (1991). Harding argues that it is impossible for a researcher to remove themselves from cultural agendas, bias, etc. and instead encourages "strong objectivity" meaning that transparency about and incorporating one's own perspectives and biases into the research is in fact far more ethical than pretending to remain objective and neutral. Thus, throughout the analysis, I leveraged my experiences and understanding of the workplace to aid in a contextual understanding of the participants' experiences.

Quality

In any research study, it is imperative that quality be systemically considered throughout the entirety of the project. Unlike quantitative research where the goal is to find generalizable findings, in qualitative research the goal is to find credible and transferable findings (Jones et al., 2013). In the following section, I provide an overview of how quality was integrated into this research through the use of the interpretive research framework developed by Walther, Sochacka, and Kellam (2013) as well as the careful integration of ethical validation throughout the research.

Quality framework

I explicitly considered research quality as guided by the quality framework as outlined by Walther, Sochacka, and Kellam (Sochacka et al., 2018; Walther et al., 2013). The quality framework highlights the importance of integrating quality throughout the entire research process breaking it down into two key categories; making and handing the data. Additionally, the authors of the framework operationalize validation and reliability into several different descriptions; theoretical validation, procedural validation, communicative validation, pragmatic validation, process reliability, and ethical validation. Ultimately, the framework is a useful tool for researchers to consider the different ways that they can integrate quality throughout all phases of qualitative research. Guided by the elements of the Q3 framework, Table 7 provides an overview of the different quality strategies that I implemented in this research.

Table 7: Quality Strategies Utilizing the Q3 Framework

Quality Consideration	**Description**	**Strategies Implemented while Making the Data**	**Strategies Implemented while Handling the Data**
Theoretical Validation	Fit between social reality observed and theory	Purposeful sampling	Emergent, inductive analysis
Procedural Validation	Fit between research design and capturing the social reality being investigated	Constant comparative method	Interpretive awareness
Communicative Validation	Fit between the knowledge constructed and the relevance within the community	Member checking (of transcripts)	Peer debriefing
Pragmatic Validation	Fit between the knowledge claims and the social reality being investigating	Diversity of participants	Present preliminary findings to others in research community (i.e., committee)
Process Reliability	Ways to make research process independent form random influences	Refined interview protocol	Analytical memos
Ethical Validation	Human aspects of qualitative research	IRB, transparency, member checking, giving choice to participants, leading with empathy	IRB, reflective memos, peer debriefing, staying true to participants words, providing findings to participants

The purpose of Table 7 is to provide a compilation of all the quality considerations as the majority of the quality strategies referenced in Table 7 have been previously discussed in this Chapter in their corresponding section. For example, I discussed purposeful sampling in Recruitment and Selection of Participants, the interview protocol refinement process in Data Collection, and peer debriefing in Data Analysis. One central quality consideration that I would like to discuss clearly and explicitly is ethical validation. As such, in the following section, I provide a detailed discussion of what I consider to be the most important aspect of research quality, ethical validation.

Ethical validation from a feminist perspective

One of the most significant components of quality in qualitative research (and in all research) is ethical validation (Sochacka et al., 2018). Indeed, ethical validation must be woven into every decision in research design and implementation (Jones et al., 2013). From my feminist perspective, it is important that my research ethics goes above and beyond simply following the IRB (Sprague, 2016). In other words, it was important to me to consider more than just participant protection and informed consent. Drawing on the guidance from Sochacka et al., (2018), I enhanced my research ethics through a deep reflection of 1) the assumptions and agenda that I have as the researcher, and 2) the ways in which I am doing justice to the participants, fellow researchers, and the broader community reading the research.

First, according to Sochacka et al., (2018), a significant ethical concern related to the assumptions and agenda that I bring to this research is that the topic of this research project and the research questions being posed are heavily influenced by my positionality and personal experiences. To address this issue from my feminist perspective, I relied heavily on the concept of “strong objectivity” from feminist scholar Sandra Harding (1991). As discussed in the data analysis section, I leveraged my “strong objectivity” during data analysis. This meant that I leaned into my own subjective experiences as an engineer in a similar context to help make sense of the data, instead of trying to separate from experience from the analysis. Additionally, throughout the research process, I tried to maintain a level of accountability to myself and to the goals of the project. I did this through ongoing researcher memos and reflections. In addition to the identity memos, I also kept a researcher journal throughout the data collection and data analysis process to help me capture my thoughts regarding the participants, the analysis, and my interpretations. Throughout the journaling, I tried to connect the work to my values, intentions, and goals of the project.

Second, while considering how I was doing justice to participants, fellow researchers, and the broader community, I drew heavily on the work of feminist sociologist Joey Sprague (2016) who titled what she described to be the ethics chapter of her feminist methodologies book, *Whose Questions, Whose Answers*. While paying homage to Harding’s (1991) book, *Whose Science, Whose Knowledge,* Sprague challenges researchers to center any ethical decision around the central concern of whom the research is for. In other words, who am I asking these research questions for and who will benefit the most from their answers. Sprague (2016) argues that “feminism is not just theory, it is a commitment to social justice that entails a political perspective on our work" (Sprague, 2016, p. 195) so we cannot leave the idea of whose questions and whose answers unexamined. Since the goal of this research project is ultimately to make engineering more socially engaged and inclusive through the further interrogation (and ultimate disruption) of the epistemic hierarchies that are pervasive in engineering, I am doing this research for current and future engineers who may not conform to normative ways of knowing and thinking in engineering.

Specifically considering doing justice to the participants, I attempted to remain ethical by being 1) transparent with my participants, 2) leading with empathy, and 3) member checking. Although there were power dynamics that needed to be navigated since some my participants (i.e., White men in positions of power) had more social power than me, it was still very ethically important to me to be as transparent as possible with my participants. Throughout the research process, I tried to always be very clear about the focus and goals of the research project. Additionally, throughout the data collection process, I attempted to build trust with the participants with the goal of creating a space where they felt they could share and reflect upon their experiences. To do this, I approached all engagement with the participants as empathetically as possible. Sprague (2016) argues that using emotions as an analytic guide when approaching interviews is a "source of important observation and insight" (p. 181). Finally, drawing on insight from feminist sociologist Sprague (2016) and a study on universalized narratives of how faculty define engineering (Pawley, 2009), I engaged in member checking by providing the participants an opportunity to review the cleaned transcripts for accuracy. I also asked if they had any additional insight to provide after reviewing the transcripts. I specifically chose to not include any of the findings from the data analysis in the member checking because Sprague (2016) warns of the complex ethical issues that can occur when the researcher and research subjects do not share the same worldview. Since I wanted to remain transparent with the participants and provide them an opportunity to review and comment on what they said during the interview, having them check the transcripts for accuracy and providing them with an opportunity to expand upon any of their previous responses was the most ethically appropriate approach to member checking. Ultimately, the participants seemed appreciative of the opportunity to review the transcripts, and no one provided additional comments to the transcripts.

Finally, while doing justice to the participants, I considered additional ethical practices for protecting vulnerable participants. A common misconception is that anonymity can be protected by simply using pseudonyms for the research participants, but indeed in qualitative research, it is often very difficult to guarantee anonymity particularly when specific experiences may make certain individuals easily identifiable (Jones et al., 2013). Given the lack of racial and ethnic diversity at the Firm, I feared that identifying the racial and ethnic identities of the participants would make certain individuals more identifiable. At the same time, I did not want to erase the participants' racial and ethnic identity, especially as it could have implications for the findings. As such, I indicated which participants were from the dominant social group (White, non-Hispanic) and those that were not. Additionally, for the participants that identified with non-dominant racial or ethnic identities as well as the gender non-binary participant, I reached out to them individually via email to ensure that they were comfortable with me sharing their stories. Specifically, I had them confirm that they were comfortable with the excerpts from their transcripts that I included in the dissertation.

Chapter 4. Findings

In this chapter, I provide the major findings for each research question. I first present the shared beliefs within a structural engineering community of practice that justify (or resist) the epistemic hierarchy of engineering. Second, I present how the reported epistemic practices of the engineers related to those shared beliefs. Finally, I present how the engineers within a community of practice relate their identity to the epistemic hierarchy of engineering.

Research Question 1

Three major themes emerged in response to the first research question, *what are the shared beliefs that engineers within a structural engineering community of practice use to justify (or resist) the epistemic hierarchy of engineering?* Figure 5 provides a visual overview of the three major themes. Specifically, I found the following:

1. The shared beliefs of engineers within the community of practice that justify the top of the epistemic hierarchy (e.g., analytical/rational thinking, practical thinking, math and science knowledge) are beliefs related to the definition of engineering.
2. The shared beliefs of engineers within the community of practice that justify the bottom of the epistemic hierarchy (e.g., empathic/emotional thinking, political knowledge) are beliefs related to the role of objectivity in engineering.
3. The shared beliefs of engineers within the community of practice that resist the epistemic hierarchy of engineering (i.e., they personally place more value in

writing and communication knowledge, creative thinking, social knowledge, emotional/empathic thinking) are beliefs related to their necessity in achieving business goals.

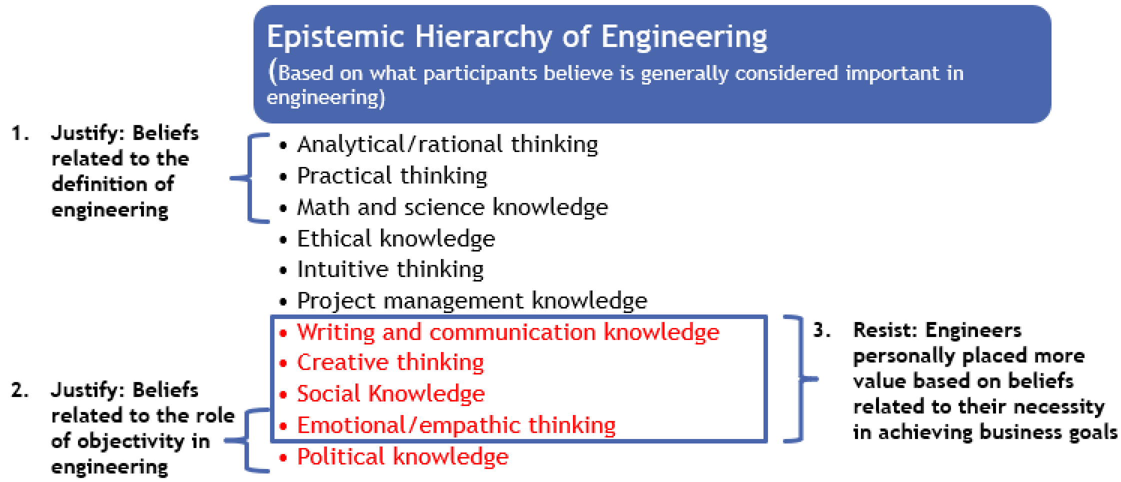

Figure 5: Overview of Findings for Research Question 1

The order of the items presented in the figure is based on the overall average order of how the participants graphically placed each item based on what they believe to generally be considered as important in engineering during the graphic elicitation exercise. Thus, the order of items in the figure represents what the engineers within the community of practice believe to be the epistemic hierarchy of engineering. Not surprisingly, this hierarchy confirms many of my theoretical assumptions regarding the epistemic hierarchy of engineering based on the literature discussed in Chapter 2. The subsequent themes are thus based on how the engineers justified (or resisted) the way that more value is generally placed on certain types of knowledge and ways of knowing over others in engineering. Finally, please note, that items in red on the figure are those that on average were placed left of the center axis (refer to Figure 3).

Theme 1 – The shared beliefs of engineers within the community of practice that justify the top of the epistemic hierarchy are beliefs related to the definition of engineering

The engineers within the community of practice justified the top of the epistemic hierarchy by leveraging what they believe to be the very definition of structural engineering. The consensus amongst the participants was that engineering is technical problem solving requiring analytical and/or practical thinking. Thus, it follows that they believe that analytical and practical thinking, as well as technical knowledge (e.g., math and science knowledge), are most important in engineering.

To be clear, the engineers did discuss that being a “good” engineer and doing “good” engineering work requires a combination of different types of knowledge and ways of knowing. Throughout the interviews, participants described many different types of knowledge and ways of knowing in engineering including writing and communication knowledge, social knowledge, creative thinking, and empathic thinking as being useful in engineering contexts. However, when the engineers were asked to rank items related to engineering knowledge and ways of knowing as well as the type of language they used throughout the interviews, it became very clear that they believe that analytical and practical ways of knowing, and math and science knowledge are the very core of structural engineering. Julia sums it up when she says,

> “*So having that* ***analytical and rational approach****, you have to be able to have it or you have to be able to learn it. And* ***if you cannot do either in a reasonable amount of time, you probably shouldn't be an engineer because that's what engineering is****.” - Julia*

In support of this theme, I found that throughout the interviews, the participants used language that implied that they believe engineering is technical work, which requires math and science knowledge, analytical thinking, and practical thinking. If participants believe that engineering is the application of math and science, analytical thinking, practical thinking then it makes sense that they would place more value on those types of knowledge and ways of knowing. For example, participants would make comments about what they believe to be “actual” engineering work. For example, when Jake was describing his day-to-day routine, he states that he begins his day by communicating with clients and contractors before getting to the “actual engineering.”

> *“Usually get there, check my emails first. See if there's anything urgent, take care of anything that has to be answered quickly, any RFIs [requests for information] that popped up overnight. My system is basically I just flag things and I'll look and organize them by day, saying, This has to be done by this day, and moving them up in terms of priority. I basically just work through and try and knock out my to-do list. Then after that I typically get to design work,* ***actual engineering.***” *– Jake*

Similarly, Alex and Julia describe what they believe is important in “actual engineering” work or what counts as “really engineering,” which do not include, for example, social skills, project management, and client communication.

> *“I feel like being too social can be a detriment at times. And just when you stack it up against the other things, I feel like social skills are less important to the* ***actual engineering****. It's more important to the project management side of things, right. So again, it's just one of those weird things where I'm trying to... My brain separates project management and engineering into different buckets.” – Alex*

> *“Like to me,* ***communication and social*** *would be the same concept. If social is more like are you willing to go out to dinner with them and that kind of thing? Then that's more of like a client management skill. It's being able to keep a client around. Keep them happy,* ***but it's not really engineering related****.” - Julia*

Additionally, participants used words like “obviously” when describing what makes a good engineer, which centered around technical competency and practicality. For example,

> *“I think you, you want someone who's* ***obviously technically competent****, um, and usually above average, technically competent” – Dan*

***"**which* ***obviously as an engineer, we're all about practicality**." – Jake*

Additionally, in support of this theme, all but one of the participants described structural engineering as the technical and practical side of architecture. Thus, if the participants share a belief that the definition of structural engineering (at least in terms of building design) is to provide technical and practical support to architects then it would make sense that they would place the most value in technical knowledge and practical thinking. Interestingly, a common story amongst the participants for how they came to be structural engineers was that they were initially interested in architecture as a career. However, once they realized that they were more interested in how a building fits together rather than its aesthetic, they switched to structural engineering. For example, Jake spoke about how despite his initial interest in architecture, he was driven away from the "artsy" elements of architecture and was drawn to the technical and practical elements of structural engineering:

> *"I originally had planned to be an architect, or at least that's what I visited schools for. I had an uncle who was an architect and had his own business, so that was the influence there. Then when I started visiting schools, it seemed a little more artsy rather than technical, which was off-putting to me. I don't know if that's the right word, but it drove me away from it, I guess. Then in just doing research,* ***structural engineering was obviously very closely related and a little***

bit more technical*…I think buildings is the main thing that interests me when it comes to architecture or structural engineering.* ***So when we'd go to these architecture schools, you wouldn't really see buildings. You'd just see abstract forms and stuff that's not really practical****." – Jake*

Similarly, Dan shared a story about his initial interest in architecture, but after learning more about the differences between engineering and architecture, his affinity for math and science, and his lack of creativity, he decided to pursue structural engineering.

*"I thought for a while that I wanted to be an architect, uh, but just not knowing the difference between architecture and engineering. I took a class in high school that's sort of, um, it's like a drafting class, sort of introduced me to CAD. Um, so we did a lot of, a lot of drafting and then our, uh, like the third class in that sequence was a class like about like architectural engineering. And I, I, during that class sort of starting to see the difference between architecture and engineering. And I was, I mean****, I like most engineers got good grades in math and science. Um, I was not a particularly artistic at all or creative****, I didn't think so once I learned that, um, what what's the difference sort of was in a, in a broader sense between architecture and engineering, I think that just sort of gravitated me towards the engineering field." – Dan*

In addition, Nichole described her experiences with architects throughout her career and her preference for structural engineering indicating what she believes to be the practical side of building design.

> *"So now I've spent almost 20 years working with architects and this is not a very flattering way to say it,* ***but [engineers have a] much more practical bend of mind****. How can we do things economically? How can we do them quickly? And I don't have that artistic vision that they have. I'm much more about how can we make things work." – Nichole*

Another shared belief amongst the participants that support the finding that engineers justify the top of the epistemic hierarchy of engineering by leveraging beliefs related to the very nature or definition of engineering, was that the participants believed that to be an engineer one must have technical knowledge and be an analytical and practical thinker. These were described as non-negotiable characteristics of engineers because again, they believed that engineering is technical problem solving using analytical and practical thinking. The participants made comments throughout the interviews indicating the knowledge or ways of thinking that engineers must possess. For example, *"But* ***the assumption of an engineer is that they're going to be very pragmatic and practical****. And the idea of being able to be an impractical engineer seems counterintuitive.* ***So I feel like that's a non-negotiable****." – Martin*

*"***Technical competency*** is the first." – Andreas*

"So with structural engineering, ***you need to be practical*** *in the end….because if you can't build it, why are you even designing it?" – Julia*

"Um, and I think it's just that what we would look for from what I would say is engineering thinking is, you know, just someone who obviously has that ***linear thought process*** *to be able to read, understand, interpret, and then* ***act in a technical standpoint****."- Dan*

Similarly, there was a shared belief amongst the engineers that one can still be a good engineer with only technical knowledge and related skills, which reinforces the notion that engineering is just technical work requiring analytical and practical thinking. Therefore, one can be a good engineer while only utilizing the types of knowledge and ways of knowing associated with technical work. Notably, the three senior-most engineers at the Firm that I interviewed, all spoke in detail throughout their interviews about the importance of writing and communication knowledge, social knowledge, creative thinking, and empathetic thinking. However, they also all made statements that although those types of knowledge and ways of knowing are useful in engineering, you can still be a good engineer and contribute to the Firm with only technical knowledge and related skills. For example,

> *"**You also need people who have no interest in talking to anybody who just want to come into work, sit down and just be technical people**. That's fine. There's a role when you get to the sort of larger companies like us, uh, every single one of those social spectrum skillsets is needed. Um, and it doesn't mean that you can't be very successful just being someone who likes to be in the books. Don't let me, I don't want to talk to people. I just want to crank out things and be done with them. You know, that type of role is just as important as someone who is very active in a very, uh, open communicator and dialogue person and has comfort levels with dealing with people and things like that." – Dan*

> *"**There are some areas where the technical expertise is paramount. And they don't need to communicate that to the end client**… those are valuable positions. There are still tasks and responsibilities that need to be done that require expertise that not everybody has. And it is okay for people to live in that world if that's what they want to do. For me, I think pairing people with their skillset and their interests is really important. That's how people do better work when they're happier and they're more engaged." – Martin*

> *"Like you could always just do the engineering side. So this is something that, like if you're looking for what the world thinks about engineering, it's good to have project management skills, but* ***you could also just run the numbers and that would get the job done.****" – Julia*

The above statements reflect a belief that although there is value in being good at skills like writing and communication or project management (or other skills related to items constructed lower in the hierarchy), in the end, the belief is that you cannot be an engineer without technical knowledge, analytical thinking, and practical thinking. The engineers believe that not utilizing the types of knowledge or ways of knowing constructed lower in the hierarchy would not necessarily be a dealbreaker in engineering, but not utilizing analytical thinking, practical thinking, and math and science knowledge would not be acceptable. Alex summed it up when they said,

> *"I feel like I have decent social skills generally, and I feel like that is an advantage that I have them, but* ***I don't feel like it's incredibly important compared to the more technical, logical skills, more hard skill****." - Alex*

The way that participants 1) used language to convey what they believe to be "actual" engineering, 2) described engineering as the technical or practical side of architecture, 3) described how engineers must be technical, analytical, or practical, and 4) described how one can still be a good engineer with only technical skills, all support the finding that engineers believe that engineering is technical problem solving requiring math and science knowledge, analytical thinking, and practical thinking. Ultimately, this shared belief is used to justify the top of the epistemic hierarchy of engineering.

Theme 2 – The shared beliefs of engineers within the community of practice that justify the bottom of the epistemic hierarchy are beliefs related to the role of objectivity in engineering.

The engineers within the community of practice justified the bottom of the epistemic hierarchy with a shared belief that engineering decisions should be made based on "objective" metrics, which do not include the use of political knowledge or emotional thinking. Indeed, all but one engineer placed either political knowledge or emotional thinking as what was generally considered to be the least important type of knowledge or way of knowing in engineering based on the graphic elicitation exercise. Additionally, the way that the participants believed that politics or emotions should not impact decision-making contributed to a lack of empowerment to contribute to or take ownership of the design decisions that result in social and political impact.

In support of this theme, I found that when the participants described why they placed political knowledge and emotional thinking as less important in engineering, particularly during the graphical elicitation exercise (which were the two items on average placed the lowest, refer to Figure 5), they did so by espousing beliefs that politics and emotion should not impact engineering decisions. For example, several of the participants talked specifically about how emotions should be left out engineering decision-making.

> *"But in relation to the industry, I think a lot of people will say you need to be thinking about, you need to be making decisions that are sound, that are all based in fact.* ***You can't just emotionally respond to situations****." – Andreas*

> *"Typically,* ***most decisions aren't made on an emotional level****. They're made on a level, what's best for the job from an economical standpoint or if you've done the job, experience." – Jake*

> *"I feel like there should be a place for it (empathic/emotional thinking), but I feel like maybe there isn't. That might be the better way to phrase it. I feel like* ***emotional thinking isn't necessarily like not looked down upon, but it isn't considered to be an asset****. I feel like a lot of times making decision out of emotion could lead to, I don't know, angering a client or hurting a relationship that could be potentially bring in money for the company." - Erica*

Furthermore, the majority of the participants spoke about how politics or political knowledge should not matter in engineering work. For example, *"My personal opinion is it should not matter. How you view the world, like to me, every person should view the world in a positive way. We should be working to always make the world a better place. There are five billion different ways to try and make the world a better place which is how politics began is that there's a bunch of different ways to do something* ***. So to me, politics should not matter*** *." -* *Erica*

Additionally, as Alex points out, the current divisive state of national politics makes them want to distance themselves from politics in general.

"I feel like ***a good engineer doesn't really allow their politics to affect their job*** *that much. For the most part, you shouldn't really be thinking too much about your politics, in my opinion. I don't, I mean, I don't really see how they should apply. Of course,* ***most of my connotations for politics right now are fairly negative anyway. So everything's just so divisive and miserable.*** *" – Alex*

Similarly, Martin also conveys a negative image about the role of politics or political knowledge in engineering. He goes as far as contrasting politics with engineering ethics.

"Political stuff, I don't know, I'm sure it's, it's very important in the ownership of companies and the management of companies. In terms of the engineering aspect of things, I'm hoping that we avoid the... ***Maybe putting ethics and political on***

> ***opposite ends of the spectrum in my chart was not intentional. But I bet when you look at your other graphs, they probably end up far away from each other quite often too****." - Martin*

Additionally, the way that Yolanda describes how engineers can "fly above" political issues implies that she too has a negative view of politics or political knowledge in engineering. She sees engineering as "above" political matters.

> *"***I think that's (passion for political issues is) great motivation to bring to your job. But I don't think that it's gonna affect your job at all****. Apart from bringing the passion to your work, which makes you interested, which makes you more attentive, which makes you more proactive, you wanna do well at it and you wanna engage people in it, I don't think that it matters at all….And so, this whole mask wearing thing has really highlighted stuff, because the way people, it enters into conversations and whether or not they think it's a hoax and all that stuff, can affect you on the job site. And so, you do have to deal with something like that occasionally, but* ***we're able to fly above all of that*** *in my interactions as a structural engineer." - Yolanda*

It should be noted that there were a couple of instances where participants did talk about the role of politics and political knowledge in engineering, which provided interesting examples of the actual role of political knowledge in engineering. For example, Andreas spoke about the importance of engineers being involved in and understanding legislation involving infrastructure, licensing, and building codes that he believes that engineers need to be involved with.

> ***I think it (political knowledge) definitely is an important factor****, because what is being passed on Capitol Hill really does impact this country's* ***infrastructure****. What our local governments are doing on the state level really impacts the types of engineers, we have in terms of you know, what are the* ***requirements for licensure, who can get licensure, what standards need to be adhered to for building codes****. Those are things that the industry as a whole needs to be definitely paying attention, paying attention to, being involved in." – Andreas*

The other example of a participant describing the role of considering political knowledge or political values in their engineering work came from Nichole. Although she ultimately did decide to separate her politics from her engineering work, she was the only participant that provided a nuanced example of how she thoughtfully considered her personal moral code and ultimately, her politics in her engineering work.

> ***"I'm a religious person. I am active in my faith and active in my religion, and that informs a big part of who I am. It informs my character at work****. It informs a lot of things.... Two different projects came up, where* ***it was designing buildings for facilities for things that went against my moral code****. And that was*

tough. And there was another engineer who happens to have a strong faith value basis. I was not talking about it. I was not talking about how uncomfortable I was. Then he said something and I'm like, 'Yeah, I'm struggling with this a little too.' He mentioned that he had spoken to his father-in-law about the issue, where do we draw the line? ***I think at the end of the day the answer was, we can't not design this building. Everybody deserves a safe place****. A physically safe place. That's a big part of what we do. Sometimes we lose sight of that in trying to keep clients happy and find all these solutions and achieve the architecture. But really what our function is to create physically safe places.* ***Separating your personal politics is difficult, because your personal politics are always tied to your personal ethics, your personal value system." -*** *Nichole*

Despite these two examples, the consensus was that empathic thinking and political knowledge should generally be left out of engineering decision-making. Although this finding is not necessarily novel (for example, Cech (2013, 2014) has written extensively about depoliticization in engineering), I also found that the way that the participants espoused beliefs that politics or emotions should not impact decision-making contributed to the lack of empowerment to influence decisions or to take ownership for the decisions they are involved in that have a social and political impact. For example, a standard follow-up question that I asked all participants during the graphic elicitation activity was to reconcile the low priority placed on political knowledge and empathic thinking with the fact that their projects have a very real social and political impact. Specifically, I asked them what they believe their role is when it comes to decisions related to sustainable design practices or the community impact of the buildings they are designing. What I found is that the majority of the participants (all but two) espoused the belief that they as engineers are not the ones to make such decisions. In other words, they deflected responsibility and espoused the belief that as consulting engineers they must follow their clients' demands. For example,

> *"I think that by the time we get involved, a lot of that stuff's already figured out. We don't really have much of a say. It's 'we want to put a building here. We want it to be a wood building. We want it to be a concrete building. We want it to look like this'. We can definitely help and say, 'We think this is more efficient than that,' or 'this has a smaller carbon footprint than that does.' But I think typically* ***it's a developer and an owner and an architect that are making those decisions and then we get involved after that,*** *at least the scale of projects I'm working on. I'm sure once you get to the really, really large things, there's different conversations." – Jake*

> *"We encourage people to start essentially making themselves as knowledgeable and expert in those areas as possible if they have a passion about, let's say, well, low carbon footprint concrete and how to do that.* ***But in the end, it's not our building, it's somebody else's building*** *and we're there to advise them." – Martin*

"I just went to was on environmental justice and racism in the workplace (seminar). I feel like I think there is a place for it and I think that there definitely is so much that we can be doing to be more environmentally conscious, but ***I'm just not in a position where I can make those decisions. That's kind of at the higher level or even at the client's level." - Erica***

Additionally, the participants discussed how the decisions related to environmental or community concerns are driven by their client's economic interests (i.e., the bottom line). For example,

"What I've seen from owners and things like that, which are the people who driving these decisions is that it comes down to the dollar. There are a lot of involved in programs that they have decided its worth it to be involved in because of initiative. Like they care about the environment, they care about LEED, the equal housing act stuff like all this stuff, and they build that into their priorities for the project. But they do that through these programs, They don't look at a detail and say what is the more environmentally conscious thing to do? What would generate the least waste? They don't do that. They enter into programs that I've seen and then they check the boxes for those programs. The architects, I've seen my clients making decisions like that, but that's often because they have a dedicated focus on that for this particular project. ***Unless the owner gives you***

> ***permission to focus on it, you can't really justify making environmental decisions that would add cost to their project.**" - Yolanda*

Similarly, Dan had an interesting discussion describing how he would handle a situation in which an engineer on his team is passionate about the community impact of their designs. He described how he would encourage that passion, but ultimately how the Firm must conform with their client's decisions. He goes on to say that those decisions are often driven by cost-effectiveness., which is often at odds with more socially conscious design choices.

> *"I would appreciate and encourage the energy that they would have, um, for whatever, whatever it is. You know, I think that, um, a cop-out answer, I think a lot is that sometimes we, as where we are on the totem pole and pecking order of how things get decided, it gets very low on the list... a lot of times we don't have any say with where buildings get put or what size they are or, or anything like that. You know, **we're not even in the realm of a discussion when those types of decisions are being made, you know**? I think those types of things are hard for us to have an immediate effect on, um, I mean obviously, you know, we always design and think about things in an efficient and economic sense to be. So, um, whether that'd be us particular project that is focused on sustainability or lead status or things like that, but again, a lot of those things, you know, um, unfortunately like everything else, you know, it, **it comes down to money costs,***

> ***you know, and if you have a developer or an owner or a builder who is on board with those kinds of ideals and principles, uh, it makes it a lot easier****. But, um, in most instances I would say that, um,* ***they are business people who are in business to make money*** *and, uh, and* ***some of these things from a social conscious and awareness standpoint just aren't high on their priority list either. So it makes it hard for us as a sub-consultant to be an activist*** *in those kinds of what you're not in a bad way to sort of promote those ideals and things like that, that, that* ***we might just not have control over****. - Dan*

Nichole had a similar response when discussing an experience she had while mentoring a younger engineer who was very passionate about sustainable practices and who was frustrated by the industry's ambivalence towards those practices. This caused Nichole to reflect on her values and how she has become disillusioned by her experiences in engineering.

> *"She's very, very interested in sustainable design. She's struggling mentally with feeling like, okay, all these things are great on paper and you should love these things, but when it comes into the real world, these experienced engineers say, "There's nothing that we can do about sustainability. That's the architect's department."* ***We're really just at the mercy of them****. When she was frustrated by that, it made me pause a minute and take a look at my own views, which probably fell a little bit in that line, because I used to be much more optimistic. So I had*

> *already started my career when lead was developed and LEED became a thing. I was super gung-ho about it at first too.* ***I started helping write my company's LEED standards before master spec built them in. I was in charge of writing some of that and quickly got disillusioned. It is tough****."* - *Nichole*

Ultimately, the way that the participants justified political knowledge and empathic thinking as not important in engineering were through the belief that they are not appropriate (or objective) ways to make engineering decisions. Moreover, the belief that politics and emotion should not impact engineering decisions has led to a lack of empowerment to influence the decisions or to take ownership for the decisions that they are involved with that have a social and political impact.

Theme 3 – The shared beliefs of engineers within the community of practice that resist the epistemic hierarchy of engineering are beliefs related to the necessity of certain types of knowledge and ways of knowing for achieving business goals

The engineers within the community of practice espoused beliefs that were indeed resistant in some ways to the socially constructed epistemic hierarchy of engineering. Specifically, when the participants described why they personally placed more value on items like writing and communication knowledge, social knowledge, creative thinking, and empathic thinking, they did so because they believe them to be necessary for achieving business goals. Figure 6 provides the order of value placed on types of knowledge and ways of knowing based on what the participants believe is generally considered important in engineering versus what they personally believe to be important. Figure 6 is used to aid in the discussion of this theme because it shows how on average the engineers personally placed more value on writing and communication knowledge, social knowledge, creative thinking, and empathic thinking than what they believe is generally considered important in engineering.

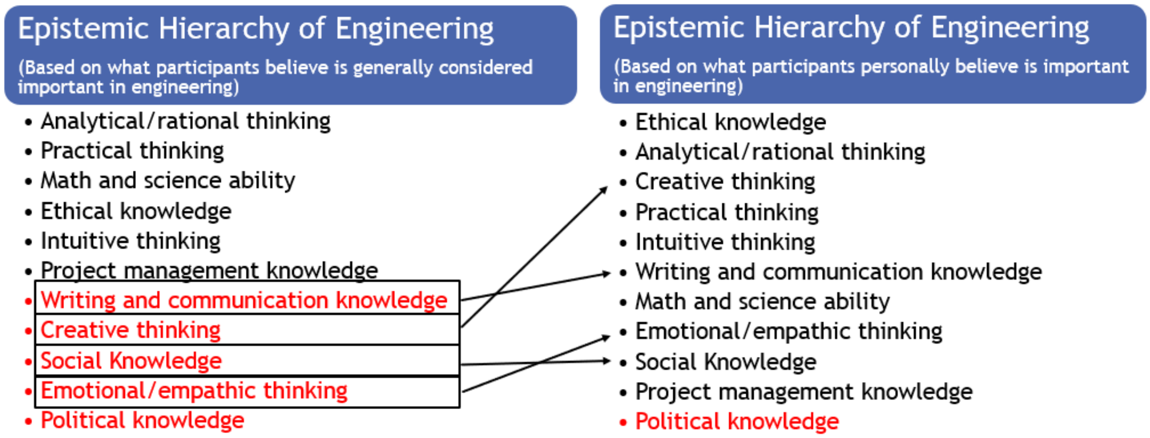

Figure 6: The Epistemic Hierarchy as Constructed by the Participants

The items in Figure 6 that are in red are the items that were on average placed below or to the left of the center axis (i.e., indicating they are of lesser importance) during the graphing exercise. I point this out because although social knowledge was ranked third from the bottom on both lists, on average the participants physically graphed that item in a way that indicated that they place more importance on it personally than what they believe it to be generally considered important in engineering.

In support of this theme, I found that overwhelmingly, when the engineers within the community of practice justified placing more value on types of knowledge and ways of knowing in engineering that are generally constructed lower in the epistemic hierarchy of engineering, they did so because they believe them to be necessary for meeting business outcomes. Indeed, the code "non-technical knowledge and ways of knowing are required in engineering consulting for relationship building with clients" was the most commonly applied code in the codebook. For example,

> *"You know, be able to go to a meeting and talk about the project and what's going on, you know, anybody can do that, but at that, at that point, the end of the project it's like well, the next step is* ***how do you get that client to come back to you****. And so, how do you, how do you get continue that communication with them, how do you* ***establish a relationship****. It, you know with* ***engineers, we're stereotypes as being very introverted. And instead we need to be more out of our comfort zone with engaging with people.****" – Andreas*

> *"I think a lot of engineers can give you a good design in terms of an efficient beam size, an efficient column size, an efficient brace size or something like that. But I think in those types of situations, the actual* ***math and science of it probably takes a backseat to developing a relationship to make sure the project goes smoothly****." – Jake*

The participants spoke specifically about the importance of writing and commutation knowledge in building relationships with clients (usually architects). For example, *"To be able to **relay complex information in a kind of not simplistic, but in an easy to understand way** just because there are some things that can't be built or can't be built how people are drawing them or how people are imagining them, **how the architect or client wants and I think it's a big necessity** to be able to kind of convey in a way that's not completely shutting down the idea, but just explaining it doesn't work in a certain way structurally."- Erica*

*"I think also just in terms of like, **when you're trying to communicate with architects and understand like what their issues or problems are**, um, it's just, **I think really important to be able to clearly communicate** that even like on a set of drawings" – Lisa*

*"Also, just **great communication skills** (makes someone a good engineer). We're (the Firm) **good at keeping the clients happy and being responsive and jumping on problems when they happened** and taking responsibility when something might've been their fault." – Jake*

The participants also spoke specifically about the role of creativity and creative thinking in engineering. Notably, during the graphic elicitation exercise, creative thinking was the way of knowing in engineering that moved up the most in terms of what was prioritized personally versus what they believed to be generally considered important by engineers. Again, the way that the engineers justified prioritizing creativity in engineering over other ways of knowing was based of the importance they places on creative thinking in terms of how it improves their marketability as a Firm and their client relationships. For example,

> ***"You don't do creative for the sake of being creative****, but I think that just needs to be* ***something you distinguish yourself just in the market*** *in general." – Martin*

> *"Creative? So that depends on the client, I think.* ***Some clients want you to be creative****. They want you to find the more economical thing. They want you to find the better solution." – Julia*

Interestingly, in addition to the creative thinking used during design, Andreas also points out the need to be creative in the ways that relationships are developed with clients. Specifically, he describes the creative thinking that can be used to find different ways to engage with clients.

> *"There's also, I think* ***creativity in terms of, related to communication and engagement with your clients on a communications level****. And from that it's you know, there is, we can always rely on a phone call and email to talk to anybody about anything but it's more of how can you be creative to be engaged with a client. Have your client want to be engaged with you and wants to come back to you to continue working with you. You know, you certainly have to be more open minded to you know,*

hey, you want to go grab a coffee, want to go grab a drink some time, go grab lunch. I've even had, you know heard of colleagues that you know will go take their clients out to you know special social functions that allow them to really get to know each other. So, you know that that requires you to be a little bit creative of how you can talk to people." – Andreas

Similarly, social knowledge was believed to be a necessary type of knowledge or skill needed in developing and maintaining business relationships with clients. Specifically, when I asked the participants why they personally placed more value on social knowledge, they spoke about social knowledge is important for navigating and developing relationships with their clients.

"With the ***social side of things****. So I think there's that in the consulting business you know, people like to work with people that they like.* ***So our clients like to hire us because they like working with us****. So, um, but I also think that, um, generally speaking, it just falls into that stereotype that, that just engineers are not necessarily people people. I just don't think that just in the broad spectrum of the engineering community, that, is placed with a higher significance of importance, you know, relative to some of the other things on that list." – Dan*

*"So **social, I think that can mean a lot of things, but it directly impacts success**. It plays into that relationship thing that we were just talking about; **relationships with clients**, relationships with others."* - *Nichole*

Finally, the participants also placed more value on empathetic thinking than how they believe it is valued generally by engineers. Again, they justified the importance of empathy using its necessity for meeting business outcomes. They espoused the belief that to be a good consulting engineer, one must understand the perspective and needs of their clients. For example,

*"I think like being empathetic, it's high on the (graph)…, I think it's looked at in a bad way, but I think **being empathetic is important, especially as kind of a project manager or other engineers working with architects**."* - *Lisa*

*"Empathetic, I personally think is a huge deal because one, so dealing inside your company or dealing outside your company**. Outside your company, you need to understand your client. And the only way you can understand them is with empathy**. You have to figure out where are they coming from? What are they looking for? You need to see inside their head to figure out what are they asking us to do."* - *Julia*

> *"Let's take truss designs, for example. Truss designs are really just back forth, that's it. It's supposed to be done. But oftentimes it's complicated. And if you are trying to see where this person is coming from and trying to understand they need to make money by doing this a certain way, that's why they're proposing it, then you're not gonna try and squash it quite as hard when they're proposing a solution...I mean, the way people handle RFIs (request for information) and* ***any kind of compensation that they need for changes and things like that, it is very dependent on the relation that the design team has with construction team. And it's also very dependent on the relationship that the design team has within it****, like with the engineer and the architect and the mechanical, whether or not you're able to efficiently get things done. So,* ***you really need to strike a balance with understanding where you people are coming from and being relatable and nice.****" – Yolanda*

Nichole too spoke about the necessary role of empathy in engineering in terms of relationship building and understanding other's goals. However, she also takes a more critical perspective in how empathy is being practiced within the Firm. She discusses how it is more directed towards clients in order to maintain relationships than it is in terms of being practiced within the company out of care.

> "*As far as success within a company,* ***I see the value of relationships being touted, hardcore.*** *And I think that that's true, but I don't see the same value given necessarily within companies to how relationships and valuing people within the*

company is lived out as opposed to directed towards a client. And ***when it's directed towards a client, it's because you want something from them****, which is really not untrue within a company too. You want good engineering services to be happening within... You want things from your employees too. And so, if we're talking about a relationship based basis in valuing relationship, a large component of that is always emotional and empathetic.* ***Empathizing with someone else's goals.****" - Nichole*

In support of this theme, I also found that engineers implicitly reinforced the importance of writing and communication knowledge, social knowledge, creative thinking, and empathic thinking through their discussion of the role of collaboration during engineering design. They espoused the belief that the best engineering designs are the result of collaboration, and that the Firm's collaborative style gives them a competitive edge. This belief (and reported practice) implicitly reinforces the finding that certain types of knowledge and ways of knowing (e.g., writing and communication knowledge, empathic thinking) are necessary for achieving business goals because these types of knowledge and ways of knowing are essential to collaborative design experiences. For example,

"The best solution then is after you figure all that out, it's what is the most structurally (sound), what is the most constructible, what is the most economical, what is the easiest to install, and what is the safest. So like ***as long as you can***

coordinate all that, that would be the best solution. And then what the client's looking for*. So you can meet all of those." – Julia*

Further, the participants also espoused the belief that engineering design must start with a collaborative and holistic understanding of the clients' needs. Essentially, they believe that as consulting engineers they are serving their clients. For example,

"The drivers are the goals of the client*. So different markets, different people are going to have different expectations or needs. And so whether it's lowest first cost, whether it's lowest carbon footprint, whether it's economy of construction is always there at some level, whether it's something technical related to vibration or whether it's just somebody who needs a handheld and a partner and somebody to coach them through a process, and just identifying what their needs and their priorities are. And it's a service industry and it's a consulting industry.* ***And so it's making sure that we're serving them****." – Martin*

Ultimately, when the engineers within the community of practice showed resistance to the epistemic hierarchy of engineering by placing more value on items such as writing and communication knowledge, social knowledge, creative thinking, and empathic thinking, they did so because of their perceived necessity for achieving business goals.

Supplemental Finding – There are subtle differences in the espoused beliefs of the engineers based on their self-identified gender and race

Throughout my analysis of the data in response to the first research question, I found that there are subtle differences in the beliefs of the participants based on their self-identified gender and race / ethnicity. To be clear, overall, there was consensus amongst the participants on the shared beliefs presented thus far in the Chapter. I consider these differences to be subtle because they were found only in a few individual codes (from the codebook developed during data analysis) not in any overall themes. However, given my feminist perspective and the importance of social relations on the experiences of engineers, these subtle differences must be explored. Specifically, I found that the differences occur around beliefs that are related to 1) the sociality of engineering knowledge engineering (e.g., the role of collaboration in engineering design, the benefit of working with experienced engineers) and 2) expected ways of knowing in decision-making in engineering (the role of political knowledge or empathic thinking in engineering decision making). Refer to Table 8 for the differences found in the beliefs of the participants based on their social identity categories.

Table 8: Subtle Differences in Beliefs based on Social Identities

Social Identity	**Related to Sociality of Engineering Knowledge**	**Related to Expected Ways of Knowing in Engineering Decision-Making in**
Women	Less likely to express the belief that engineering design requires collaboration	More likely to express the belief that political knowledge should not be considered during engineering decision-making
Non-dominant race and ethnicity	More likely to express the belief that the best source of knowledge is *not* other engineers, but rather in resources found on their own	More likely to express the belief emotional thinking should not impact engineering decision-making

These subtle differences in the beliefs across self-identified gender can provide powerful insight into how the social structure of gender (and race) manifests within a community of practice. For example, although women are typically associated with valuing collaboration in engineering spaces, they were less likely to express beliefs that engineering requires collaboration. When considering the social structure of gender, a potential explanation could be that due to women's negative experiences during collaborative experiences, they are less likely to express the importance of collaboration in design. This finding along with the other subtle differences will be further explored and related to literature in Chapter 5 in the section, *Gender and Ways of Knowing.*

Research Question 2

In response to the second research question, *how do the self-reported epistemic practices of engineers within a structural engineering community of practice relate to the shared beliefs used to justify (or resist) the epistemic hierarchy of engineering?,* I found one central theme indicating that there are tensions between the shared beliefs and reported epistemic practices of the engineering within the community of practice.

Theme 4 – There are tensions between the shared beliefs and reported epistemic practices of the engineers within the community of practice

During the analysis, I looked for patterns and themes across the participants' espoused shared beliefs and their reported epistemic practices. What I found is that there are key areas of tension between the participants' espoused beliefs and their reported practice.

Figure 7 provides an overview of the beliefs and reported epistemic practices that I found to be in tension with each other.

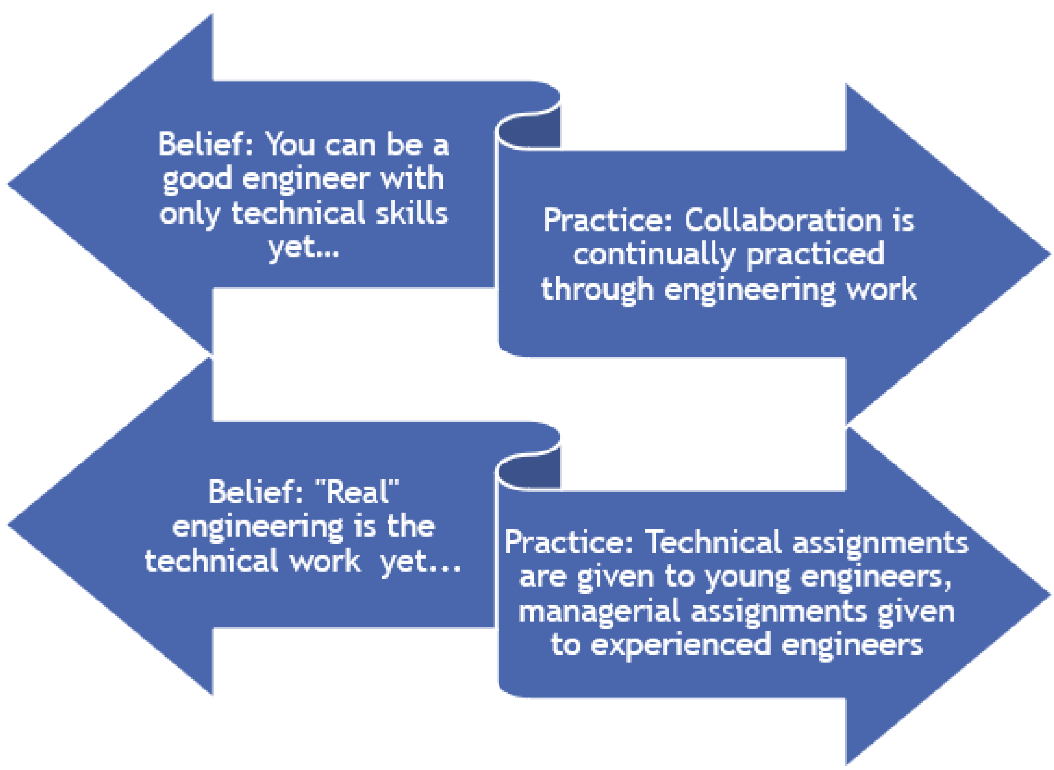

Figure 7: Tensions Between the Shared Beliefs and Reported Epistemic Practices

First, I found tension between the belief that one can be a good engineer with only technical skills and the reported practice that collaboration is continually utilized throughout their engineering work. As presented in the first theme, there was a pervasive shared belief amongst the participants that one can be a good engineer using *only* technical-related knowledge and ways of knowing. This was particularly salient amongst the engineers that were members of the Firm's leadership. However, I also found that throughout the interviews the engineers reported that collaboration was fundamental to the engineering design process. They reported how collaboration with both other engineers and with architects, owners, and contractors was continually practiced during all phases of design at the Firm. For example,

> *"**it's (design decisions) usually more in that collaboration that takes place between an architect and an engineer and a mechanical engineer**. And, you know, **more often than not, that's sort of where we operate in, in those kinds of situations** where, um, whether it be a beam is too deep or a column is in the way of something, or there's a conflict with a mechanical duct or a piece of equipment, you know, so it's, it's, I think part of it is recognizing and then understanding what the other players needs are, and then, um, making sure they also understand what's happening with our needs and, and our challenges" - Dan*

> *“**Every day is a sort of like firefighting with answering emails, phone calls,** reviewing shop drawing submittal…I definitely tried to be on top of requests from the contractor or an architect” - Andreas*

Seeing as collaboration requires the application of non-technical knowledge and ways of knowing, if engineering requires constant collaboration, then it doesn’t make sense that one can be a good engineer while only utilizing the types of knowledge and way of knowing associated with technical skills.

To be clear, there were reported epistemic practices associated with the application of technical knowledge and ways of knowing. For example, the participants reported epistemic practices related to the step-by-step design procedures and the computer-aided design tools they utilize while performing design calculations. Yet, the reported epistemic practices related to continuous collaboration were pervasive.

Another interesting tension found between the shared beliefs and the reported epistemic practices of the engineers within the community of practice were related to the distribution of responsibilities amongst the engineers. As reported in the first theme, there was a shared belief amongst the participants that “actual” or “real” engineering is the technical, detailed design work. Yet, it was commonly reported by the participants that at the Firm the younger, less experienced engineers were given the technical design tasks. They are the engineers that are doing the detailed calculation work. For example, Erica who is a less experienced engineer at the Firm describes herself as a number cruncher.

"I just kind of ***run the numbers… doing the grind work of the calculations****."- Erica*

Similarly, Yolanda though more experienced than Erica, described a recent project where she was supporting a more experienced engineer.

I actually had a project recently where I was more supporting and just doing the project engineer role, which is not really talking to the client so much, just ***design the main components of the building****." - Yolanda*

On the other hand, the more experienced engineers were often given managerial assignments; they managed budgets and schedules, spent hours in meeting with clients, mentored younger engineers, or worked on larger firm planning or business development initiatives. For example, Dan who has been with the Firm for many years described his typical day as,

"*Not as much production-related anymore. It's more just team management. It's more proposal writing. It's more larger firm initiatives and things like that. A lot of individual team member development kind of stuff, you know, a lot of more QA [quality assurance] reviews than it is actual production itself." - Dan*

Where I find the tension between the shared beliefs and reported practices is that by following their logic, it would mean that the most experienced engineers at the Firm are no longer doing the "real" engineering work.

Ultimately, these key areas of tension between the participants' espoused beliefs and their reported practice speak to the pervasiveness of the epistemic hierarchy of engineering. The types of knowledge and ways of knowing in engineering that are associated with the "technical" are constructed as superior (e.g., analytical thinking, math and science knowledge), even though they do not always reflect the epistemic practices of engineering.

Research Question 3

One major theme emerged in response to the third research question, *how do engineers within a structural engineering community of practice relate their engineering identity to the epistemic hierarchy of engineering?* I found that engineers within the community of practice who identified as women or gender non-binary and those with less power at the Firm were more likely to identify with analytical thinking. Conversely, those who identified more strongly with types of knowledge and ways of knowing that are generally constructed as lower in the epistemic hierarchy of engineering were all engineers in positions of power at the Firm and were mostly men. Additionally, those that identified strongly with non-normative types of knowledge and ways of knowing viewed it as something that made them more a more well-rounded or versatile engineer.

Theme 5 – Those who identified a women or gender non-binary and held less power at the Firm were more likely to identity with analytical thinking

The engineers within the community of practice that identified most strongly with analytical thinking were more likely to identify as women or gender non-binary and hold less power within the Firm. Presented in Figure 8 is the data display graphic I created during data analysis based on my interpretation of the participants' relationship to power within the community of practice. I based the participants position in the figure on the number of years at the Firm, their job title, and their overall attitude towards the Firm (more details for how I created the figure are in *Chapter 3, Data Analysis*). After mapping onto Figure 8 the types of knowledge or way of knowing that each participant seemed to identify the most with, I came to an understanding that being able to identify with engineering, be identified by others as an engineer, and be able to associate that identify with a non-normative type of knowledge or way of knowing in engineering (e.g., creative thinking, empathic thinking) is a privilege in engineering.

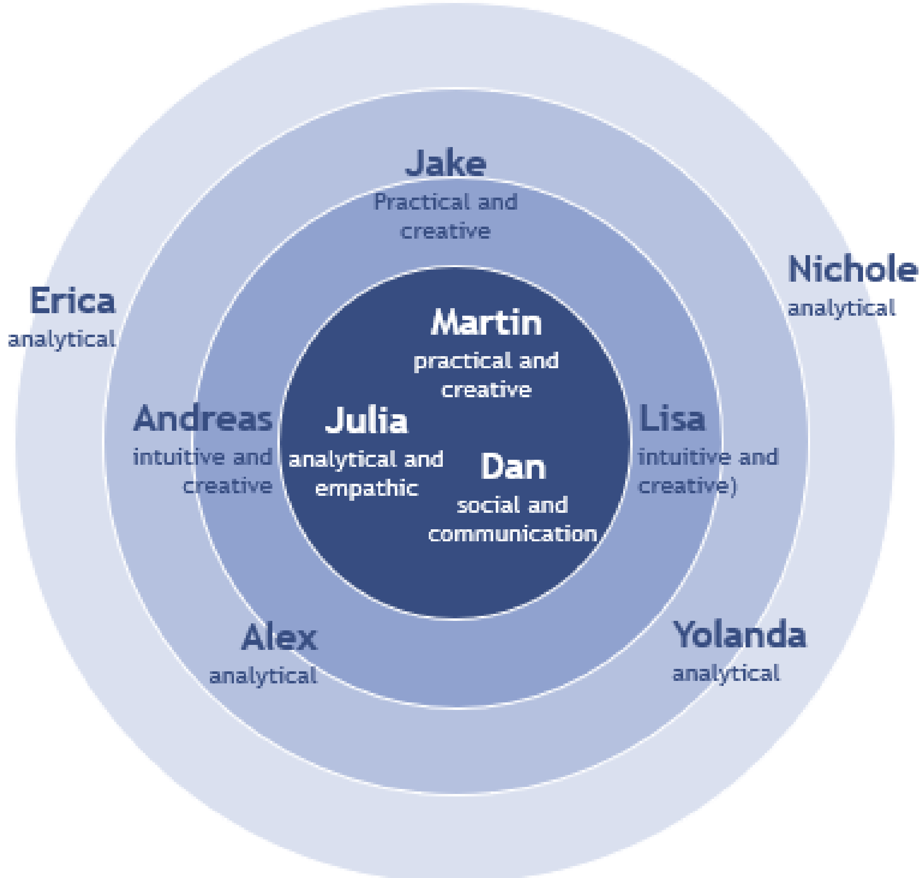

Figure 8: Identity, Ways of Knowing, and Power within the CoP

As depicted in Figure 8, the participants more on the periphery of the community of practice (e.g., Erica, Nichole, Yolanda, Alex) all strongly identified with being analytical thinkers, which of course is at the very top of the epistemic hierarchy of engineering. On the other hand, those with the most power in the community of practice (e.g., Martin, Dan, and Julia) strongly identified with at least one type of knowledge or way of knowing that is generally considered not as important in engineering.

Of course, the concept of power is deeply connected to the social structures of gender and race (Harding, 1991). Thus, to unpack the relationships more closely between power and ways of knowing within the community of practice, the participants' gender and race must also be included. Table 9 presents the participants listed in order of their centrality to power within the Firm along with their self-identified gender, race and ethnicity, and the type of knowledge or way of knowing that they identify with most strongly.

Table 9: Identity, Ways of Knowing, Gender, and Race/Ethnicity within the CoP

Participant (ranked by centrality to power at the Firm)	**Gender**	**Race/Ethnicity**	**Engineering knowledge or way of knowing they identify with and value most**
Martin	Man	Dominant	Practical thinking and creative thinking
Dan	Man	Dominant	Social knowledge and writing and communication knowledge
Julia	Woman	Dominant	*Analytical thinking* and empathic thinking
Andreas	Man	Minoritized	Intuitive thinking and creative thinking
Lisa	Woman	Dominant	Intuitive thinking and creative thinking
Jake	Man	Dominant	Practical thinking and creativity thinking
Alex	Non-binary	Dominant	*Analytical thinking*
Yolanda	Woman	Dominant	*Analytical thinking*
Nichole	Woman	Dominant	*Analytical thinking*
Erica	Woman	Minoritized	*Analytical thinking*

Those that identify as women or gender non-binary (except for Lisa) identified strongly with analytical thinking. I find this particularly compelling given that it contrasts that pervasive stereotype associating masculinity with the “technical” (or the analytical/rational) and femininity with the “social” (Faulkner, 2007). Not surprisingly, the participants that identified strongly with analytical thinking discussed their initial interest in engineering based on their interest in or being identified as good at math or science and being “technically-minded.” This could indicate that those that identify as women or gender non-binary who pursue engineering are those that see themselves as analytical thinkers from a young age and that identity then holds throughout their career.

However, the participants who identified as men had similar stories for why they became interested in engineering (e.g., good at math and science), yet as their careers have progressed, they have been able to lean into and see value in different aspects of their engineering identity. For example, Dan is a self-described “engineering nerd.” He spoke a lot about doing well in school (particularly in his math and science classes) and being socially awkward. However, he has since learned the value of social knowledge, writing and communication knowledge, and collaboration in engineering. He spent most of the interview talking about how important those types of skills are to the Firm and to him personally. Although, he still sees himself as a “linear thinker,” he prides himself most in his ability to collaborate and build relationships as an engineer. Martin had a very similar story with his ending in him identifying with and placing much value in engineering creativity.

A potential explanation for the finding that those who identify more with analytical thinking (e.g., the top of the epistemic hierarchy of engineering) are those with less social power and less power within the Firm can be explored through the story of Erica. Erica, a woman of color, spoke about how being rational is a necessity for her in engineering. She spoke about this in terms of how others view her and treat her as an engineer.

Erica: ***I just have a very rational personality myself, so I feel like that's why I identify more with it,*** *and I feel like that definitely has helped me in this industry just because I don't get upset at things easily and I don't take things to heart too quickly. I kind of think through things very evenly****. So think that's beneficial, especially being a woman****.* ***You kind of have to take things... or roll with the punches.***

Interviewer: So you said especially being a woman, so why do you say that?

Erica: I think people are very... if you're on site, it's very easy to react quickly to things that people say or workers. They just like... I mean, I don't know if you've experienced that at all, but they just make comments. They don't mean anything by it, ***but they don't necessarily expect you to be the engineer.***

Although not explicitly discussed as the reason why they identify most with analytical thinking, it must be noted that every participant who identified as a woman brought up at some point in the interview a professional experience where their expertise was questioned, or an experience where they were not given the same level of challenging assignments as their male counterparts. None of the men brought up such experiences. I cannot make causal claims based on my data, but it follows that if one's engineering identity is being questioned or diminished by others, they would then lean more heavily into aspects of their engineering identity that are most accepted in engineering, such as analytical thinking. The discussion of this finding is expanded upon in Chapter 5, in the section, *Gender and Ways of Knowing.*

When considering Julia, who is a woman in a leadership role at the Firm, it is striking how she can identify with multiple ways of knowing in engineering. She still very strongly identifies with being an analytical thinker, but she also can strongly identify with empathy in engineering. Unlike the other women (except Lisa), she is able to identify strongly with a non-normative way of knowing (i.e., empathic thinking). Additionally, it's important to point out that Julia still centers analytical thinking as the core of her engineering identity. She perceives her empathy (as well as her writing and communication knowledge and social knowledge) as making her a more "professional" engineer as opposed to what she calls a "technical" engineer.

> *Julia:* ***The professional engineer is not just an engineer****. It is everything else. It is the project management side. It's the communication.* ***It's the being able to interact with people, to think about people.*** *So there's the technical engineer and then there's the professional engineer.*
>
> *Interviewer: What do you think you identify most with?*
>
> *Julia:* ***I am so a professional engineer. I love people.***

Indeed, identifying with types of knowledge and ways of knowing that are generally constructed as less important in engineering was a way that the engineers described themselves as unique or more well-rounded engineers, specifically for those with well-established engineer identities. For those participants, they viewed it as something that made them more appealing than other engineers. For example, Lisa (the only woman who did not identify most strongly with analytical thinking) saw her creative thinking as something that sets her apart from other engineers. Although she still prefers the technical work, she views her creative thinking is what makes her unique.

> *Lisa: I really enjoy the like drawings and like the, putting the building together and* ***being creative, um, having that intuition*** *on. So I guess, yeah,* ***I think it's just important to me because I think that there are a lot of especially young engineers that don't necessarily have that****. And I think it's, um, it's just, it's, it's a skill that can be, it's hard to learn… think it's an important skill. That's maybe harder to find in engineers sometimes.*
>
> *Interviewer: And it sounds like it's something that you identify with and makes you feel, you know, maybe unique, kind of like, your niche..*
>
> *Lisa: Yeah*

Likewise, Jake, an ambitious young White man engineer at the Firm, describes himself as a well-rounded engineer. He takes a lot of pride in his practicality, and his relationship-building skills.

> ***I see myself as a pretty well-rounded engineer****…in terms of* ***practicality****…And I think the* ***personal skills*** *are definitely a big thing and something I've tried to work on. Yeah, I think those do align with what I see in myself. - Jake*

Similarly, Martin and Dan were two of the engineers that expressed the belief that one can still be a good engineer with only technical knowledge and ways of knowing. So, when they expressed the value they place in their creative thinking, writing and communication knowledge, or social knowledge, they described it as contributing to their success and advancement to leadership positions.

Ultimately, being able to strongly associate one's engineering identity with a type of knowledge or way of knowing that is typically considered as not as important in engineering is relational to power and is a privilege. It seems that one must already have a well-established engineering identity (as viewed by themselves and by others) to be able to go outside of the norms of the profession. Additionally, they view those aspects of their engineering identity as a way that makes them a more well-rounded engineer.

Chapter 5. Discussion and Conclusions

In this study, I qualitatively explored the beliefs, reported practices, and identities of engineers within a structural engineering community of practice to further interrogate how the limited and exclusionary epistemic hierarchy of engineering is reproduced. In the previous chapter, I presented the findings from my data analysis for each of the research questions. In this chapter, I will discuss the findings as well as the implications of this work. Finally, I will end with a discussion of the limitations of this research and how it shapes my future research agenda.

Discussion

In the following section, I provide a detailed discussion of the findings. Although it has been established that certain types of knowledge and ways of knowing are constructed as superior in engineering, my research contributes much-needed insight into the shared beliefs that reproduce what "counts" as legitimate engineering knowledge and what it means to "think like an engineer" within a specific professional engineering community of practice. My work also provides insight into the gendered ways that engineering identity is negotiated within a community of practice relative to ways to knowing in engineering.

The epistemic hierarchy of engineering is pervasive

Not surprisingly, my analysis revealed that the engineers within the community of practice espoused beliefs that reinforced the socially constructed epistemic hierarchy of engineering. In other words, the findings confirmed my theoretical assumptions presented in Chapter 2, specifically that analytical or rational thinking and technical knowledge (i.e., math and science knowledge) are considered the superior types of knowledge and ways of knowing in engineering. This finding aligns with research indicating that the social-technical divide continues to be pervasive in professional engineering spaces with "real" engineering consistently being associated with the technical (Cech, 2014; Faulkner, 2000; Stevens et al., 2014). Additionally, the way that the engineers associated analytical thinking, practical thinking, and math and science with engineering was so deeply engrained that the participants could not really justify their beliefs other than by stating that they are the definition of engineering. In other words, they believed that analytical thinking and applying math and science knowledge are what makes an engineer an engineer. Assumptions that engineering is the application of math and science align with Pawley's (2009) study on the "universalized narratives" of engineering as constructed by engineering faculty. She found that a central way that faculty articulate what "counts" as engineering is that engineering is the application of math and science.

Additionally, my finding regarding the tension between shared beliefs and reported epistemic practices also demonstrates the pervasiveness of the socially constructed epistemic hierarchy of engineering. For example, even though engineers spoke in detail about the collaborative nature of nearly every aspect of the design process, they simultaneously espoused the belief that one could be a good engineer with only technical skills. I interpret this finding as revealing the complexities of how beliefs, meaning, and practices are negotiated within a community of practice (Wenger, 1998).

Beliefs exist at the individual and cultural levels and are complexly related to broader cultural norms and values (Dringenberg et al., 2019). Ultimately, my findings reveal the power of the cultural assumptions and beliefs that support the epistemic hierarchy of engineering because those beliefs persist even when they do not always align with the day-to-day practices of their engineering work.

To be clear, the engineers within the community of practice did espouse beliefs that many different types of knowledge and ways of knowing can be useful in engineering. However, they continued to describe certain types of knowledge and ways of knowing as required (e.g., analytical thinking), whereas others (e.g., creative thinking) were framed as helpful additions. The way that types of knowledge and ways of knowing (e.g., writing and communication knowledge, creative thinking) are considered as helpful but not really required in engineering, I interpret as simply another way of reinforcing the epistemic hierarchy of engineering. In other words, if creativity is just considered as a helpful bonus skill, then it is clearly not as important as say, analytical thinking. I point this out because there is research indicating that employers seek to hire engineers that value and possess the types of knowledge and ways of knowing that relate to, for example, communication and social skills (De Graaff & Ravesteijn, 2001). But ultimately, the engineers within the community of practice still made value judgments based on what they considered as required (e.g. analytical thinking, math and science knowledge) and what they considered to be helpful additions (e.g., writing and communication knowledge, creative thinking, social knowledge) in engineering.

Finally, I wanted to comment on what Beddoes et al., (2017b) describes as the need to "square" philosophical assertions about engineering epistemology with the actual beliefs of practicing engineers. Overall, I found several key differences between the findings of this research and philosophical assertions about engineering epistemology. Specifically, my findings indicate the pervasiveness of the socially constructed epistemic hierarchy of engineering that places the least amount of value on types of knowledge and ways of knowing that are most closely associated with the "social" (e.g., social knowledge, political knowledge, empathic thinking), which does not align with philosophical assertions that engineering knowledge and ways of knowing should be deeply connected to societal goals and concerns. Specifically, scholars have argued that engineering should be a deeply social enterprise that requires engagement with society (Bucciarelli, 2003) and that an epistemology of engineering should include dimensions for thinking about an engineer as a humanist as well as a designer, a scientist, and a craftworker (Adams et al., 2011). My findings provide further evidence for the lack of consensus between scholars and practicing engineers regarding what it means to be an engineer and what it means to think like an engineer (Adams et al., 2006; Kant & Kerr, 2019). In other words, despite certain philosophical assertions, the epistemic hierarchy of engineering constructing analytical thinking and "technical" knowledge as superior is pervasive.

The myth of objectivity and value-neutrality contributes to an uncritical acceptance of authority and a culture of compliance in engineering

Not surprisingly, my analysis revealed that the engineers within the community of practice espoused the belief that engineering decisions should not include considerations for political knowledge or empathic ways of knowing. In other words, they believe that engineering decisions should be made based on what they believe to be objective metrics. Like the previous discussion point, this finding indicating the engineers believe that they should not let politics or emotion influence their work speaks to the pervasiveness of the epistemic hierarchy of engineering, which constructs emotional thinking and political knowledge at the bottom of the hierarchy (For example, Cech, 2014).

Further, the finding indicating the engineers believe that they should not let politics or emotion influence their work aligns with ideologies associated with positivism or scientific epistemology (Riley, 2008). These ideologies emphasize the importance of objectivity and value-neutrality in science and engineering, which are problematic myths (Riley, 2008) that (as discussed in Chapter 2) feminist scholars have long cautioned against (Harding, 1991). Social forces are always at play that demand the use of certain technology or methods, or in the problems that are deemed relevant enough to be solved by engineers (Riley, 2008). Furthermore, when engineers believe that political knowledge or empathic ways of knowing should be excluded from engineering work, it leads to a culture of disengagement in engineering (Cech, 2014) as well as "(mis)frames" social justice efforts as not relevant in engineering (Cech, 2013). In other words, the myth of objectivity in engineering leads to lack a of social engagement and involvement in social justice efforts.

Similarly, the way the participants believed themselves to be “objective” contributes to an uncritical acceptance of authority and ultimately, a culture of compliance in engineering. In other words, when engineers assume that they are making decisions based on “objective” metrics, they do not learn how to critically examine the subjective and value-laden aspects of their work. For example, my findings indicate that there was a lack of empowerment to influence decisions or to take ownership for the decisions that participants were involved in that had a social and political impact (e.g., environmental or community impact of their structures). Specifically, they spoke about how they had to conform to the decisions made by others; that they were at the “mercy” of their clients. Riley (2008) attributes the ease at which engineers accept non-technical decisions made by authoritative figures to a positivistic (i.e., “objective”) mindset. Specifically, she discusses how a lack of exposure to “other” ways of knowing results in an uncritical acceptance of authority in engineering.

> *“a lack of exposure to other ways of knowing, or contexts in which those other ways of knowing are valued, can lead to a lack of questioning of certain types of information. When (engineer) do not learn to question the information given to us, we are unlikely to question authority.” (Riley, 2008, p. 42)*

Due to this lack of exposure to ways of thinking outside the norm of engineering (e.g., rationalism, objectivism), engineers are not taught how to question authority or to critically reflect on the social, political, or environmental impact of their work. For example, in my research, when I asked Jake how he reconciles the fact that he does not think politics should influence engineering decision-making with the very real environmental, community, and political impact of the structures he designs, he responded that it is not something he thinks about; he complies with the decision made by others and does not include himself amongst those that are responsible for how the building affects the community.

> *“* ***It's not something I've really ever thought about with my projects.*** *Maybe that isn't the best answer because maybe I should be, but like I said,* ***it's never been a discussion I've had as far as what we think the best decision is here from a political standpoint or that it doesn't affect this population in a negative way.*** *I think when it comes to the decision makers and the developers and the people that are building these buildings, I think that's definitely something that it* ***should be at the forefront of*** **their** ***decision making and hope it is****.” - Jake*

The result of the uncritical acceptance of authority and the lack of critical reflection on the impact of their work is that it creates a culture of compliance in engineering, which can be dangerous. When engineers are socialized to comply; to perform the technical work they are given without question, they remain ignorant to the potential negative environmental or social consequences of their work (Baillie, 2006).

In defense of the engineers within the community of practice, as consultants, the reality is that they do need to work within the constraints of their clients' demands to stay in business. Consulting is their livelihood and the engineers that I interviewed have families to provide for. Yet, the finding that engineers believe that political knowledge or emotional thinking should not be considered in engineering decision making and the overall lack of empowerment to contribute to or take ownership of the design decisions that have a social and political impact is troublesome. Without making explicit how the socially constructed hierarchy of engineering contributes to an uncritical acceptance of authority and a culture of compliance, there is the danger that engineers will remain ignorant to the potentially harmful consequences of their work.

Although there are benefits to promoting the "business side" of engineering, there is danger in leaning into capitalistic and neoliberal ideology

When the engineers within the community of practice resisted the epistemic hierarchy of engineering, or in other words, placed value on types of knowledge and ways of knowing typically constructed as less important in engineering (i.e., writing and communication knowledge, social knowledge, creative thinking, and empathic thinking), they did so through a capitalistic lens. Rather, they justified prioritizing non-technical knowledge and ways of knowing through the belief in their necessity for developing and maintaining business relationships with clients, which translated to financial gains and the economic competitiveness of the Firm.

First, I interpret this finding as evidence for the potential power of emphasizing business-related outcomes as an entry point to encourage engineers to consider the value in types of knowledge and ways of knowing in engineering typically constructed lower in the epistemic hierarchy. Within engineering education, researchers have shown that incorporating business or entrepreneurial education into the engineering curriculum can lead to positive outcomes for students, including an improved mindset, motivation, and development of interpersonal skills (for example, Bosman & Fernhaber, 2019; Rae & Melton, 2017; Sababha et al., 2020). Additionally, according to the nationally recognized Kern Entrepreneurial Engineering Network (KEEN), an entrepreneurial mindset among engineering undergraduates encourages social consciousness through consideration of stakeholder needs and communicating societal value in engineering projects (Rae & Melton, 2017).

Although emphasizing business-related outcomes in engineering has benefits, there are also very clear limitations and potential problems with leaning fully into the business side of engineering. Specifically, placing too much value in business-oriented goals and outcomes in engineering promotes capitalist agendas and neoliberal ideology, which are often at odds with social welfare and social justice concerns (Riley, 2007). Although there is no clear consensus as to a definition of neoliberalism, it is most often associated with economic and political policies that promote an unwavering faith in free-market capitalism, competition, and individualism (Vallier, 2021). Critiques of neoliberal ideology argue that it results in economic inequalities, undermines democracy, and is a hallmark of colonial regimes (Vallier, 2021). It has also been closely associated with meritocratic ideology (i.e., belief that success is the result of individual talent and skill, not social factors) (Vallier, 2021). Meritocratic ideology has been shown by researchers to be problematic in engineering as it promotes a culture of disengagement in engineering (Cech, 2014), "(mis)frame" social justice in engineering (Cech, 2013) and perpetuates the beliefs that "not everyone" can be an engineer (Rohde et al., 2020).

Within engineering, neoliberal ideology manifests by prioritizing the economic interests of a private company over other factors (e.g., social or environmental welfare) during engineering design work. Although neoliberal ideology is pervasive in the United States (Monbiot, 2016), there is limited work within engineering education research that has explicitly explored the relationship between neoliberal ideology and engineering. One such paper that did address neoliberalism in engineering encouraged engineers to resist neoliberalism (Riley, 2007). When discussing global development engineering, Riley (2007) argues that,

> *"underlying most engineering projects at any scale is an unquestioning acceptance of capitalism and free markets. This often leads to an unspoken or even unwitting acceptance of neoliberal approaches that advantage the United States and other developed countries. Without a conscious resistance of neoliberalism that asks questions about who benefits and who loses, it is very easy to end up with a situation that does not profit the intended beneficiaries at all."(Riley, 2007, p. 3)*

Ultimately, Riley (2007) argues that neoliberal ideology in engineering leads to unjust outcomes.

With this research, I have contributed empirical evidence of the presence of neoliberal ideology in an engineering community of practice. Neoliberal ideology was evident in my findings in the way that the participants were only be able to express a resistance to the epistemic hierarchy of engineering through business-related outcomes. For example, I found it striking that when discussing empathy, the engineers did not discuss empathy in terms of trying to empathize with who would be using, constructing, or benefiting from their designs, but rather in terms of empathizing with their clients so to develop their business relationships ensuring the economic success of the Firm. Additionally, neoliberal ideology was evident in the way that the engineers within the community of practice accepted that their clients often prioritized the "bottom line" over environmental or community welfare when making decisions about their projects (as discussed in the previous section).

I do understand that the engineers within the community practice are consultants working in a capitalistic system and thus it makes sense that they would cite business-oriented goals as a way of expressing value in certain types of knowledge and ways of knowing not typically associated with engineering. However, given that the participants could only express a resistance to the epistemic hierarchy of engineering through neoliberal discourse, I conclude that engineering educators should teach engineers (students and professionals) about the implications of neoliberalism in engineering, which should include a deep reflection regarding who is and is not truly benefiting from their work (Riley, 2007).

Gender and ways of knowing in engineering impact the experiences and identity negotiation of engineers within a community of practice.

My analysis revealed two key findings that provide insight into how the social structure of gender interacts with engineers' knowledge-related beliefs, practices, and identities. First, I found subtle differences in the beliefs of the participants based on their self-identified gender and race. Given the power of social structures (e.g., gender and race) in how our society is constructed (Connell, 2009), the fact that there were only subtle differences, again, speaks to the pervasiveness of the epistemic hierarchy of engineering. Particularly, it reflects the power of cultural beliefs in engineering that construct technical knowledge and analytical ways of knowing as superior (Cech, 2014).

When considering how the subtle differences in the beliefs of the participants relate to the social structures of gender and race, we can start to unpack the gendered and racialized implications of ways of knowing on the experiences of engineers. To start, I categorized the subtle differences into beliefs reflective of the 1) sociality of engineering knowledge and 2) expected ways of knowing in engineering decision-making (refer to Table 8, Chapter 3). Regarding the sociality of engineering knowledge, I found that women were less likely to express the belief that engineering design requires collaboration. This may seem counterintuitive as femininity is widely associated with cooperation and care. However, as Faulkner (2009) found during her fieldwork of engineering workplace culture, it is easier for men to build relationships in engineering workplaces and feel a sense of belonging. Thus, women may be less likely to express the value of collaborative knowledge-sharing experiences because it is more difficult for them to build collaborative relationships in the workplace.

Similarly, the participants that held non-dominant racial or ethnic identities were less likely to espouse the belief that other engineers are the best source of engineering knowledge. Given that Black engineers experience bias, isolation, microaggressions, and racism in the workplace (Dupuy et al., 2018; Williams et al., 2016), it would make sense that racially minoritized engineers are not getting the same level of support while seeking help from other engineers, resulting in them placing less value on using other engineers as a resource.

Additionally, when considering the differences in beliefs about expected ways of knowing in engineering decision-making, I found that women were more likely to express the belief that political knowledge should not be considered during engineering decision-making, and participants holding non-dominant racial or ethnic identities were more likely to express the belief emotional thinking should not impact engineering decision-making. Again, this may seem counterintuitive as women and underrepresented minority engineers are often assumed to be at the forefront of equity and social justice initiatives where political knowledge and empathic thinking are more valued. However, we can further unpack this finding when considering how engineers who identify as women and/or people of color report that they feel as though they consistently have to prove themselves over and over again to get the same level of respect and recognition in the workplace as their majority counterparts (Williams et al., 2016). Thus, if you are constantly having to prove yourself in a workplace that places little to no value in political knowledge or emotional thinking, then you may be more likely to say that there is no room for politics or emotion in engineering work. Ultimately, the subtle differences in beliefs of the participants provide insight into how gendered and racialized experiences impact engineers' beliefs about knowledge and ways of knowing.

The second key finding that provided insight into how the social structure of gender interacts with engineers' knowledge-related beliefs, practices, and identities was that those that identified as women or gender non-binary and held less power at the Firm were more likely to strongly identify with analytical (i.e., the top of the epistemic hierarchy of engineering). Again, this finding may seem counterintuitive because masculinity is often associated with technical or analytical ways of knowing in engineering (Faulkner, 2007) so one may expect that men would identify more with analytical or rational thinking. However, I interpret this finding as powerful evidence that being able to identify with engineering, be identified by others as an engineer, and be able to associate that identity with a type of knowledge or way knowing constructed lower in the hierarchy (e.g., creative thinking) is a privilege.

I support the claim that is it a privilege to be able to identify with engineering and associate that identity with a type of knowledge or way of knowing constructed lower in through the concept of identity congruence. Identity congruence is the idea that for one to feel a sense of belonging in a group, there needs to be some sort of congruence between aspects of the members' social identities and their identification with the practices (i.e., operational identity) and ways of knowing (i.e., knowledge-related identity) of the group (Hughes, 2010). Wenger (1998) describes that in a community of practice, as engineers move from the peripheral to full membership, they are negotiating their identities within that space. So one's ability to move from peripheral participation to full membership is mediated by many factors and requires social, operational, and knowledge-related identity congruence (Hughes, 2010). Given that engineering (and the community of practice at the center of this research) is dominated by White men, it makes sense that those with incongruent social identities (e.g., women, people of color) would lean more into the knowledge-related identity most closely associated with engineering (i.e., analytical thinking). In other words, engineers who are non-men and non-White, have to identify more with accepted ways of knowing in engineering (i.e., analytical thinking) to be accepted within the community of practice. Whereas those that already have congruent social identities (e.g., White men) have the privilege of holding more diverse knowledge-related identities.

The need for women to identify with analytical thinking in engineering is further compounded by the fact that technical knowledge and analytical ways of knowing are strongly associated with masculinity (Faulkner, 2007). What this means is that the knowledge-related identity that is required for women to gain acceptance in engineering (i.e., analytical thinker) is the one that is most associated with masculinity. Thus, if feeling a sense of belonging in engineering requires knowledge-related identity congruence and that knowledge-related identity is associated with masculinity, then it makes it even more necessary for women to express their identification with ways of knowing that are constructed as superior in engineering.

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Implications and Recommendations

The findings of this research presented in Chapter 4 and discussed in the previous section have several key implications for stakeholders of engineering education research. In the following section, I will discuss the implications of this work and provide recommendations for engineering education researchers, engineering educators, and practicing engineers.

Implications for engineering education researchers

In general, this work advances the field of engineering education research through the advancement of knowledge of the shared beliefs that reproduce what “counts” as legitimate engineering knowledge and what it means to “think like an engineer” within a professional engineering community of practice. While previous researchers have provided insight into the epistemic hierarchy of engineering and others have provided philosophical assertions regarding what engineering epistemology should be, this work contributed empirical evidence of the shared beliefs that justify (or resist) the epistemic hierarchy of engineering. Engineering education researchers can build upon the empirical evidence presented in this research indicating that there is a tendency for engineers to hold an uncritical acceptance of authority and a culture of compliance in engineering as well as the role of neoliberal ideology in engineering practice. Further research exploring how to combat the culture of compliance in engineering and neoliberal ideology in engineering is warranted.

Additionally, engineering education researchers can also use this work when considering the relationship between beliefs about knowledge and ways of knowing and epistemic practices. Specifically, I found several instances where beliefs and practices do not align. These findings imply that the cultural assumptions and norms surrounding what “counts” as engineering and what it means to “think like an engineer” are so pervasive that they are in tension with the collaborative epistemic practices of engineering. This finding provides interesting implications for researchers studying beliefs as it is often assumed in engineering education research that beliefs will predict behaviors (Kramer, Leonard, et al., Forthcoming). Future work can further explore the relationship between beliefs and practices in engineering.

Finally, for engineering identity researchers, the findings of this research indicate that there are gendered differences in how engineers within a community of practice relate their engineering identity to ways of knowing in engineering. This implies that future work in engineering identity research should explicitly consider epistemological or “knowledge-related” identity as well as social identities in the formation of engineering identity.

Implications for engineering educators

My findings indicate that the epistemic hierarchy of engineering is pervasive with technical knowledge and analytical ways of knowing constructed as superior and justified through beliefs about the very definition of engineering and the role of objectivity in engineering. As engineering educators, we are in a powerful position to set the tone for our students and provide them with opportunities for critical reflection regarding what "counts" as engineering and what it means to "think like an engineer." Past efforts such as changing the conversation about engineering to include messaging about how engineers solve problems to better people's lives (National Academy of Engineering, 2008) or even encouraging engineers to be boundary agents (Adams et al., 2011) do not seem to be enough to disrupt the epistemic hierarchy of engineering. Even when engineers place value on types of knowledge and ways of knowing that are generally constructed as inferior in engineering, my work implies that engineers still think of it as more of a bonus skill and consider "real" engineering the technical work. This way of thinking only continues to reproduce the epistemic hierarchy of engineering. Instead, I draw on the recommendation from Cech (2013) who argues that without making space for explicit discussion of pervasive cultural assumptions in engineering, they will continue to be reproduced. Thus, if we are serious about disrupting the epistemic hierarchy of engineering, which is needed to promote social engagement and inclusivity in our classrooms, then based on my findings we must make space in our curriculum for continued:

- deep and explicit integration of "other" ways of knowing in engineering (e.g., integrate activities and explicitly teach about the role of creativity and empathy during design problems; integrate critical reflection of how work impacts social welfare, social justice, and the environment; introduce the concept of "strong" objectivity)

- explicit disruption of the myth of objectivity and depoliticization in engineering (e.g., introduce critiques from feminist science and technology studies scholarship) and,
- discussions about the role of capitalism and neoliberal ideology in engineering and how it can lead to unjust outcomes.

Ultimately, we are preparing students for the "real" world and the reality is that students will encounter engineers who value the technical or the "bottom line" over anything else in the workplace. However, as engineering educators, we have an obligation to empower students (and professionals) to think deeply about how their work impacts society and how to consider their own subjectivity during decision making. By doing so, engineering educators can provide students with the tools to think more critically about their engineering work and to be change agents in the profession if they want to be.

Implications for practicing engineers

This work can provide powerful insight for practicing engineers into the cultural norms and (hidden) assumptions within their engineering communities of practice. In addition to the recommendations provided for engineering educators, this work also implies that practicing engineers could benefit from critically examining:

- how their beliefs relate to their day-to-day practices,
- how they may be uncritically accepting authority in their work, and

- how their own engineering identity relates to their social identities and knowledge-related identity

Again, I argue that there is need to make space for practicing engineers to have opportunities to reflect on their own beliefs and to make explicit for them the implications of the epistemic hierarchy of engineering. Such reflective exercises could provide a powerful professional development opportunity for practicing engineers. By not doing so, engineers will continue to implicitly reproduce the epistemic hierarchy of engineering that is limited, fosters exclusion, and often do not align with their actual practices as engineers.

Limitations

There are several major limitations of this study. First, given the complex nature of the conceptual framework and exploratory nature of the study, I was not able to deeply dive into each component of the conceptual framework, but rather provided a broad range of findings related to the beliefs about knowledge and ways of knowing, epistemic practices, and identities of the engineers within the community of practice. Thus, future work is needed to further understand and unpack the nuances and directionality of the relationships between the constructs of the framework.

Another major limitation of this study is that due to the nature of the conceptual framework, it is very context-specific. In other words, I was only able to explore the beliefs, practices, and identities of engineers from one community of practice. Like all qualitative research, the findings are only transferable to similar communities of practice, similar contexts, and a similar participant demographic sample. Future work is needed to explore more communities of practices to determine how shared beliefs and practices as well as the identities of engineers compare and contrast across differing contexts.

Finally, a significant limitation of this work is that I was not able to fully explore how the social structure of race relates to the shared beliefs, practices, and engineer identities of the engineers within the community of practice. Although, there were subtle differences found in the beliefs of the participant based on their self-identified race, the lack of racial diversity in the community of practice (and in my sample) made it difficult to draw any meaningful conclusions regarding the racialized experiences of the engineers. Future work is needed to account for the social structure of race and the racialized implications of the epistemic hierarchy within engineering communities of practice.

Future Research Agenda

Through this research experience, I have gained insight into several key areas of future research that I would like to build upon. First, my dissertation work is an in-depth study of one professional community of practice, in other words, one specific context. In future work, I would like to explore multiple engineering contexts to uncover the similarities and differences in how epistemic hierarchies are constructed and reproduced broadly within engineering. For example, I would like to explore engineering communities of practices that perform government work (e.g., Departments of Transportation, County engineers' offices), research and development, non-profit work, as well as varied disciplines of engineering. Also, given the lack of racial diversity in this research, in future work, I would like to more deeply explore how the social structure of race relates to engineers' beliefs of knowledge and ways of knowing, their epistemic practices, and their knowledge-related identity.

Additionally, I am very interested in a study focused solely on exploring the relationship between normative ways of knowing in engineering and professional engineering identity. Specifically, I would like to build upon the concept of identity congruence across multiple dimensions of identity (e.g., social identity and knowledge-related identity) and explicitly explore how that relates to a sense of belonging and acceptance in engineering.

Finally, throughout this project, I found evidence of several key cultural ideologies that influence the epistemic hierarchy of engineering. Specifically, depoliticization (i.e., belief that engineering should be separated from social and political concerns) and neoliberal ideology were evident throughout the findings. In future work, I would like to establish a research program utilizing qualitative, mixed, and critical methods to explicitly explore the relationship between normative ways of knowing in engineering and the ideological beliefs that perpetuate (or disrupt) socially constructed hierarchies in engineering. A graphical representation of the constructs centered within my research agenda is included in Figure 9.

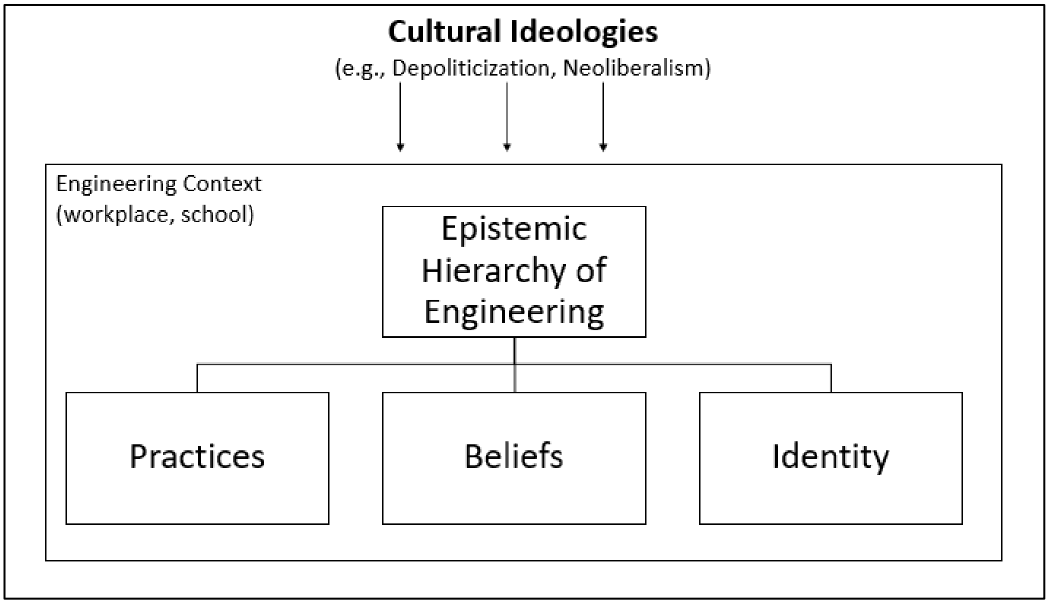

Figure 9: Overview of Future Research Agenda

With an emphasis on engineering practice, in future work I aim to continue to disrupt these hierarchies and empower students and professionals to think deeply about what it means to be an engineer in today's ever-changing and global society.

Conclusions

This research demonstrates that the epistemic hierarchy of engineering is pervasive in a professional engineering community of practice and reproduced using beliefs related to what is assumed to be the definition of engineering and assumptions about the role of objectivity in engineering. Unfortunately, the most pervasive shared beliefs used to resist the epistemic hierarchy of engineering are rooted in neoliberal ideology, which is troublesome because it is often at odds with social justice and equity initiatives. Finally, this research demonstrated the engineers who identified as women or gender non-binary were more likely to strongly identify with normative ways of knowing in engineering (i.e., analytical thinking) than their majority counterparts, which provides insight into the role of privilege in the way that engineering identity is negotiated within a community of practice in relation to the epistemic hierarchy of engineering. In other words, it indicates that being able to identify with engineering, to be identified by others as an engineer, and to be able to strongly connect that identity to ways of knowing like creativity or empathy is a privilege

Ultimately, this work implies that to disrupt normative ways of knowing in engineering, there is a need to make explicit how the deeply pervasive, limited, and exclusionary epistemic hierarchy of engineering is reproduced. Specifically, I recommend making space for students and professionals to critically reflect on what it means to think like an engineer, the myth of objectivity and value-neutrality in engineering, the role of authority in their decision making, how capitalist agendas and neoliberal ideology can lead to unjust outcomes, and the implications of their identification with certain types of knowledge and ways of knowing in engineering. Additionally, for engineering educators, I recommend we deeply integrate "other" ways of knowing throughout all aspects of the engineering curricula. By doing so, we can provide powerful opportunities for students and professionals to expand their conceptions of what it means to think like an engineer, which will lead to a more socially conscious and inclusive engineering field.

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Appendix A. Recruitment Survey

Participant Recruitment Survey (to be distributed using Qualtrics)

[CONSENT DOCUMENT ADDED HERE]

1. Are you 18 years of age or older?
    a. Yes
    b. No

    [If no, skip to end of survey.]

2. How long have you been a practicing engineer?
    - 0-5 years
    - 6-10 years
    - 11-15 years
    - 16-20 years
    - 21+ years

3. In 1-2 sentences, please briefly describe your professional background and career trajectory (e.g., what type of projects do you typically work on?, what kind of role are you currently in?)
    - Write in box

4. In 1-2 sentences, please describe what it means to think like an engineer?
    - Write in box

5. How do you describe yourself?
    - Man
    - Woman
    - Non-binary
    - Prefer to self-describe
        - Write in box
    - Prefer not to identify

6. What is your ethnicity?
    - Hispanic or Latinx
    - Not Hispanic or Latinx
    - Prefer not to identify

7. What is your race? Please check all that apply.
    - African American or Black
    - Caucasian or White
    - South Asian (e.g., Indian, Pakistani, Bangladeshi, Sri Lankan, etc.)
    - East Asian (e.g., Chinese, Korean, Japanese, etc.)

- Other Asian
- American Indian or Alaska Native
- Native Hawaiian or Other Pacific Islander
- Hispanic or Latinx
- Other
    - Write in box
- Prefer not to identify

8. Is the United States your original country of origin?
    - Yes
    - No
    - Prefer not to identify

9. By providing your contact information here you are indicating that, if selected, we may contact you for an interview. All responses will have identifying information removed in order to maintain confidentiality.
    a. Name (first, last)
    b. Email

Appendix B. Interview Protocol and Graphic Elicitation

Interview #:_____

"Thinking Like an Engineer" – Investigating the Epistemic Boundaries and Hierarchies of Engineering Practice

Date: ______________________________
Time: ______________________________
Interviewer: ________________________
Pseudonym: ________________________

Before beginning the interview, the researcher will review the interview consent form with the participant.

Logistics
Hello! Thank you for volunteering to participate in this interview. First, I want to let you know what to expect.

- Our conversation will be recorded and then transcribed verbatim. This allows me to revisit what was said accurately and eliminates the need to take notes frantically. Any identifying information will be removed from the transcript and the audio will be kept in a secured location.
- Your name will be replaced with a pseudonym--do you have a preferred pseudonym (for next letter--fill in above)? Also, what are you preferred pronouns?
- I may take some notes along the way, so that I can keep track of things to follow up on without interrupting you.
- The interview should be about an hour to an hour and a half and is completely voluntary—you can stop at any time.

Purpose

- Our goal today is for us to have a detailed discussion about your experiences as an engineer and your views on what counts as engineering knowledge and what it means to think like an engineer as well as how you identify with these things.
- I want to hear your own thoughts and perceptions— I am expecting that they will be different from the thoughts of others—there is no right or wrong answer.
- I aim to understand your perspective, so I will ask questions like "what do you mean by that?" These types of questions can be a bit awkward and may require you to reflect on what you've experienced, so I will purposefully leave long pauses after my questions. Take your time--if you need clarification, please let me know.
- Do you have any questions for me before we begin?

[Start recorder]

<u>Interview Questions</u>

Background and Context

1. Why did you choose to pursue structural engineering?
2. Tell me a little bit about your professional experience.
3. Epistemic Practices: Tell me a little bit about your current position and your day-to-day work life.

Engineering Epistemology / Personal Epistemology

Now I am going to ask you some general questions related to your views of the structural engineering profession.

1. Generally speaking, what does it mean to do "good" structural engineering work?
   a. What makes someone a good structural engineer?
2. Generally speaking, what does it mean to "think like an engineer?
3. In the projects that you work or your day-to-day work life, what are the limits of your abilities. What kind of problems/projects are you (and other structural engineers) not qualified to solve?

Epistemic Practices

Now I am going to ask you a few general questions about some projects you've worked on.

4. What is your "typical" approach to a structural engineering design problem? Give me an example and tell me what you did.
   a. How do you decide what information or assumptions you were using were right or true?
   b. Are there multiple "right" answers to your problem? If so, how did you determine what's best?
5. What do you do when you are stuck or don't know how to proceed on a design problem?
6. What do you consider your best design or project? Tell me about that experience? What did you do?

Graphic Elicitation Exercise

**See attached document*

***Follow-up Questions:*

7. Please explain your graph to me and why you placed the items where you did?
   a. You placed xxx as generally considered most important by important by structural engineers, why do you think others values this?
      i. What would you say to another engineer who says xxx is least important in structural engineering?
   b. You placed xxx as generally considered most important by important by structural engineers, why do you think others values this?

        i. What would you say to a young engineer who says xxx is most important in structural engineering?
    c. You placed xxx as most important to you, why is it most important to you?
        i. Could you give me an example or experience in practice of you using xxx.
        ii. [If different] Why is it different than what you placed as most important?
        iii. How does this relate to how you view yourself as an engineer?
    d. You placed xxx as least important to you, why is it the least important to you?
        i. Could you give me an example in practice of you using xxx.
        ii. [If different] Why is it different than what you placed as least important?
        iii. How does this relate to how you view yourself as an engineer?
8. How would the "best" structural engineer you know graph these items?
9. Which one of these items do you personally relate to the most?

Identity

Keeping in mind what we've been discussing, I'm going to ask you some general questions about how you view yourself as an engineer.

10. When did you first start to feel like an engineer (e.g., college, practice, PE?)
11. Is being an engineer a big part of who you are?
12. In thinking about the graph from earlier in the interview, which one of these items do you personally relate to the most? Which makes you feel most like an engineer?
13. Do you feel like you can be yourself when you are doing your engineering work?

Synthesis and Conclusion

14. Now that we've talked about what engineering knowledge and ways of knowing, is there anything you'd like to add or is there anything that you I should have asked you about engineering knowledge and ways of knowing?

[Inform participant about gift card process]
[turn off the recorder]

Graphic Exercise: Engineering knowledge and ways of knowing

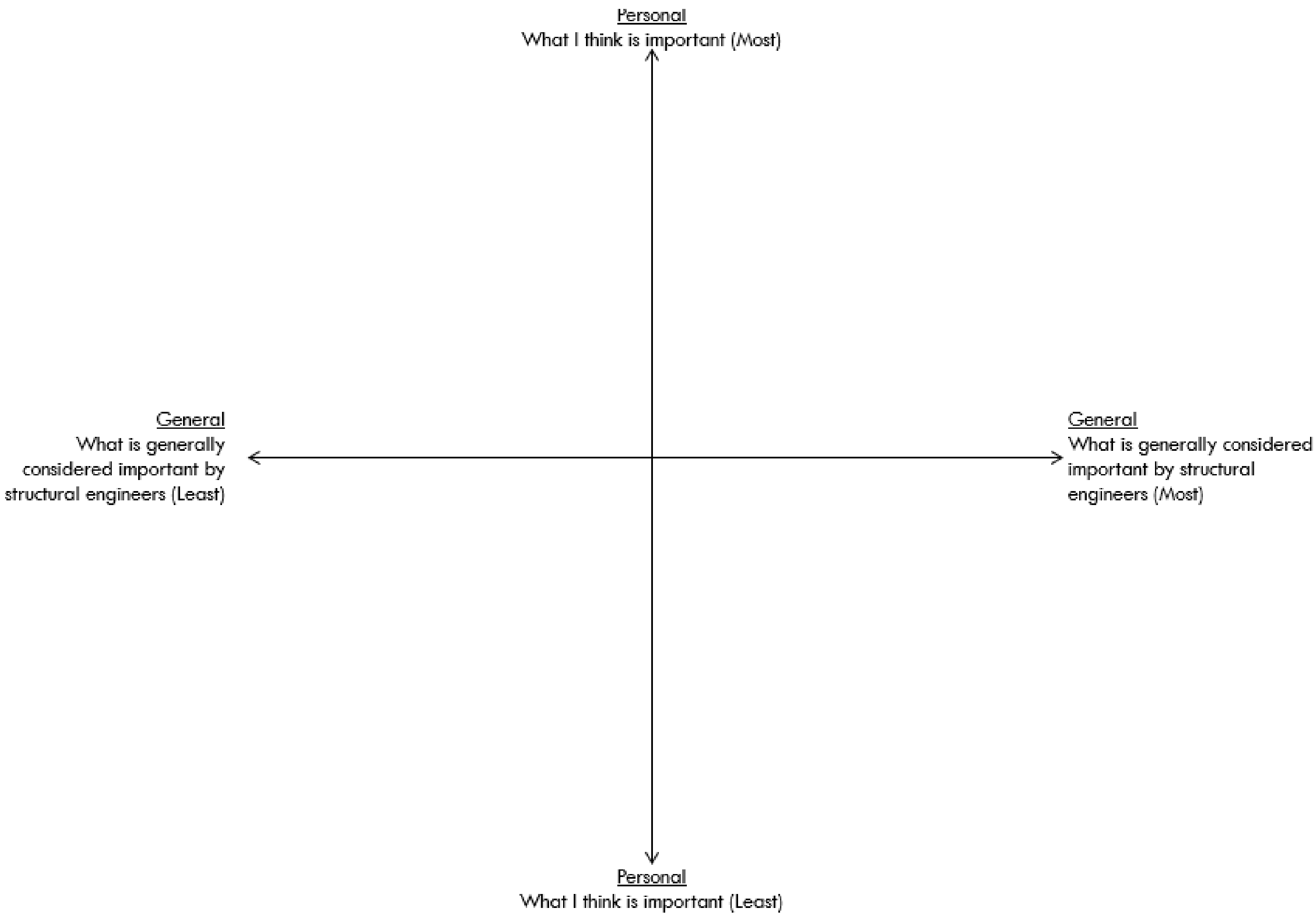
Please place the following items on the graph below based on what type of knowledge or ways of thinking *you* find most important or valuable in your structural engineer work versus what you think *other structural engineers* generally consider to be important or valuable in structural engineering work:

Engineering Knowledge:

1. Ethics knowledge
2. Math and science knowledge
3. Project management knowledge
4. Writing and communication knowledge
5. Social knowledge
6. Political knowledge

Ways of knowing:

7. Analytical/rational thinking
8. Emotional/empathic thinking
9. Practical thinking
10. Intuitive thinking
11. Creative thinking
12. Other (fill in)



Appendix C. Codebook

Construct	Category	Label	Main Code	Subcode 1	Subcode 2	Subcode 2
Beliefs	Beliefs about engineering, engineering knowledge and ways of knowing	1.a.	Structural engineering is the technical/practical side of architecture			
		1.b.	"Real" engineering is technical work and requires analytical and/or practical thinking			
		1.c.	Engineering requires a combination of knowledge and ways of knowing			
		1.d.	Engineering creativity is outside the box thinking, needed to make architects vision reality			
		1.e.	Ethics is about ensuring safety and following codes	other		
		1.f.	Writing and communication is fundamental in engineering, how engineers communicate designs to clients			
		1.g.	Math and science are the tools of engineers			
		1.h.	Non-technical knowledge and ways of knowing are required in consulting for relationship building with clients			
	Beliefs about engineering knowledge and ways of knowing involved in design and decision making	2.a.	Engineering design / decision making is ambiguous -- there are always multiple "right" answers"			
		2.b.	The "best" solution is always determined through collaboration	with clients	with engineers	
		2.c.	The design process starts with "big picture" understanding of problem/building	of client's needs		
		2.d.	Politics and emotion should not impact engineering decisions	just emotion	just politics	anti
		2.e.	Engineering design requires collaboration	with clients	with engineers	
		2.f.	Design decisions that have sociopolitical impact are made by client / others			
	Beliefs about what kinds of knowledge and ways of	3.a.	Engineers must have technical knowledge, be analytical and/or practical thinkers	anti		

	knowing are required of "good" engineers	3.b.	You can be a good engineer with only technical skills			
		3.c.	Engineering ways of thinking (e.g., analytical, practical, intuition) are innate			
	Beliefs about sources of engineering knowledge	4.a.	Experienced engineers are a great source of knowledge	other		
	Beliefs about engineering education in learning engineering knowledge and ways of knowing	5.a.	Non-technical knowledge and skills are learned through experience	anti	technical knowledge	
		5.b.	Engineering school is lacking			
		5.c.	Engineering School only places importance on technical knowledge and analytical ways of knowing			
Epistemic Practices	Practices related to roles and responsibilities at the firm	6.a.	Assigning young engineers technical tasks (i.e., young engineers are the "number crunchers)			
		6.b.	Assigning young engineers mentors			
		6.c.	Assigning more experienced engineers managerial assignments (i.e., expierenced engineers spend most of time in meetings)			
	Practices involving design	6.d.	Practicing collaboration with project team and client throughout design process and construction			
		6.e.	Designing through a step-by-step analysis process			
		6.f.	Designing using structural engineering software and tools (Models, analysis software, in-house spreadsheets)			
	Practices specific to the firm	6.g.	Organizing company with clearly defined roles for the various level of engineers			
		6.h.	Promoting a positive, collaborative culture	anti		
		6.g.	Prioritizing work over social life (i.e., there is a lot of pressure from deadlines at the Firm)			

Appendix D. Identity Memo Template

Identity Analytic Memo Template

Pseudonym (gender, race, ethnicity, years of experience, position at the firm):

1. From this interview, what stands out about this participant?

2. How does the participant identity with engineering? What types of knolwedge or ways of knowing does the participant identity with the most?

3. How does the participant distinguish themselves from other engineers; generally speaking, and within their community of practice?

4. How do aspects of the participant's social identity (e.g., gender, race) relate to how they see themselves as engineers and their experiences (implicitly and explicitly stated)?

5. How do I relate to the participant? How does my positionality relate to how I interpret the data?