Eurocentrism in Engineering: Consequences for Teamwork in Engineering Design

by

Trevion S. Henderson

A dissertation submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
(Higher Education)
in The University of Michigan
2021

Doctoral Committee:

Professor Lisa R. Lattuca, Chair
Associate Professor Erin A. Cech
Professor Bruce A. Desmarais, Pennsylvania State University, University Park
Professor Cynthia J. Finelli

Trevion S. Henderson
tshend@umich.edu
ORCID id: 0000-0003-43190-1700

Acknowledgements

I would like to acknowledge the financial support of the Rackham Graduate School, the Center for the Study of Higher and Postsecondary Education, and the Center for Academic Innovation. This project would not have been possible without the generous financial support of my colleagues and peers across the University of Michigan.

I would first like to thank the participants in this study—Team Mobula, Team Surge, and The Yachtsmen—who invited me into their teams for this research. It was an incredible experience getting to know, learn, and grow with you all over the course of this project. Thank you so much for sharing this experience with me. I wish you all the best of luck in your endeavors in engineering and beyond!

I would also like to thank my committee—Lisa, Erin, Bruce, and Cindy—who saw me through this study. We could not have foreseen how a pandemic might alter this process, but I am so fortunate to have had the support of brilliant scholars and mentors to see me through this. Thank you for sharing your expertise in ways that helped me grow as a researcher over the course of this eventful dissertation experience.

I would also like to acknowledge Dr. Ted Chen, whose work on the multilayer.ergm package both in the past and explicitly in support of this dissertation research was instrumental in the development of this project. Thank you for sharing your knowledge and expertise with me. I am deeply excited to see where this work takes us!

I would also like to acknowledge the scholars who saw this project in its earliest stages, offering feedback that would shape it into the document that follows. Drs. Phillip Bowman, Camille Wilson, Robin Fowler, Laura Alford, and Mike Brown—I thank you for your scholarly support of this work.

This project, and indeed my entire academic career, was truly a community effort. I owe thanks to my peers, colleagues, mentors, friends, and family who offered their time, feedback, and expertise in various ways that shaped this project and my PhD experience. To the Lattuca Research Team, The Finelli Lab, and my colleagues at Academic Innovation—I thank you for your support during my time at Michigan. It has truly been a pleasure to learn and grow as a scholar and person in your presence!

I had the pleasure of entering my doctoral program with a group of incredibly caring and supportive scholars. To my cohort—Nue, Paula, Selyna, Raúl, Yiran, and KC—We did it! Thank you for being on this path with me. I cannot wait to see what the future holds for us!

I would like to acknowledge my dear friends, Katie Shoemaker, Gordon Palmer, and Jeff Grim, who offered the trifecta of close friendship, scholarly feedback, and more than a few timely happy hours. I thank you all for loving me through this process! Our lunches, weekend writing sessions, and "Friday Meetings" were such a pivotal part of this experience, and I thank you for sharing these five years with me.

I thank my siblings, Torri, John, and Christopher, for their years of love and support. It is most incredible that we have somehow grown closer precisely in the moments the physical distance between us has grown larger. Your phone calls, visits, and messages in the family thread have sustained me through this process. I love you all dearly, and I'm excited to see what the future holds for our family.

I thank my parents, John and Deborah. I have questioned many things in this life, but I have never, for a moment, questioned your love for me. Your love and support over this experience has meant the world to me. Dad: I know that “How’s the car?” phone calls were your way of saying “I was thinking about you, and I wanted to hear your voice.” Mom: I’ve always been able to feel your love from across the country. This accomplishment is the culmination of all you’ve done for our family. We did it!

Finally, to my incredible advisor, mentor, and friend, Dr. Lisa Lattuca. When I was deciding between programs, a former Michigan student told me, “I did not know I needed an advisor as good as Lisa, until I had Lisa as my advisor.” Everyone I know raves about your leadership, mentorship, caring support, and friendship at Michigan, and to all those reading this—Lisa is as advertised! It was the best decision I could have made to come to Michigan and join your team. It is perhaps my greatest endeavor to be to my future students what you have been for me. From the bottom of my heart, Lisa, thank you for everything!

Table of Contents

List of Tables

List of Figures

List of Appendices

Glossary of Terms

Action Opportunity

In Status Characteristics Theory, action opportunities represent the opportunities granted to, or taken by, members of a team to contribute to the work of the team (Simpson, Willer, & Ridgeway, 2012).

Depoliticization

According to Cech and Sherick (2015), the ideology of depoliticization in engineering refers to the belief that engineering work is technical, should be carried out *objectively*, and should be devoid of social bias. The ideology of depoliticization in engineering "sanctions the separation of social justice concerns from engineering work" (Carter, Duenas, & Mendoza, 2019, p. 71) and undermines the need for students to develop an understanding of engineering work in relation to the cultural, social, and political contexts (Cech & Sherick, 2015).

Diffuse Status Characteristics

In Status Characteristics Theory, diffuse status characteristics, such as race and gender, entail domain-general beliefs that having one state of a characteristic (e.g., White, male) is assumed to be more valued (e.g., more qualified, more intelligent) than other states of the characteristic (Black, female). For example, Kant and Kerr (2018) describe the mythical scientist and mythical engineer as "typically a man" and argues this myth "reveals something more deeply ingrained in our understanding of ourselves and our place in the world (p. 19).

Engineering Design

Dym, Agogino, Eris, Frey, and Leifer (2005) define engineering design as "a systematic, intelligent process in which designers generate, evaluate, and specify concepts for devices, systems, or processes whose form and function achieve clients' objectives or users' needs while satisfying a set of constraints" (p. 104). Since this work in many ways critiques the definition provided by Dym et al. (2005), it may be more appropriate to adopt the more simple view of design as a form of complex, ill-structured problem solving in engineering.

Epistemological Beliefs/Personal Epistemologies

This work is informed by several definitions of epistemological beliefs. Kitchener (1983) defined epistemological beliefs as one's beliefs about the limits, certainty, and sources of knowledge. This baseline definition has been expanded by critical race scholars. For example, Ladson-Billings (2000) argues that epistemologies are not "ways of knowing", but "systems of knowing that have both an internal logic and external validity" (p. 257). In this dissertation I focus on three core values of the Eurocentric system of thinking: scientific objectivity, value-neutrality, and the ideology of depoliticization in engineering.

Influence

In Status Characteristics Theory, influence refers to the ability of individuals to utilize conscious or unconscious social pressures to modify opinions, expectations, decisions, or behaviors (Simpson, Willer, & Ridgeway, 2012) in team settings.

Performance Evaluations

In Status Characteristics Theory, performance evaluations represent the positive or negative evaluations of individual or collective contributions to the team (Simpson, Willer, & Ridgeway, 2012).

Performance Outputs

In Status Characteristics Theory, performance outputs represent the collection of individual contributions to the work of a team (Simpson, Willer, & Ridgeway, 2012).

Scientific Objectivity

Grincheva (2013) argues objectivity refers to the utilization of specific ways of observation or experimentation in knowledge production and truth claims. Relatedly, Reiss and Springer (2017) define objectivity in terms of two different forms: product objectivity and process objectivity. Product objectivity refers to the idea that the product of science and engineering work (i.e., laws, theories, observations) is objective and represents "accurate representations of the world." Process objectivity refers to the idea that scientific processes (e.g., methods of observation and measurement, reasoning) are absent normative commitments and individual values. These concepts are closely related to the definitions of value-neutrality and the ideology of depoliticization.

Status Characteristics

In Status Characteristics Theory, status characteristics are “any recognized social distinction that has attached to it widely shared beliefs about at least two categories, or states, of the distinction” (Bianchi, 2010, p. 3). SCT distinguished two types of status characteristics: diffuse and specific status characteristics.

Specific Status Characteristics

In Status Characteristics Theory, specific status characteristics are traits specific to a limited domain (e.g., perceptions of one’s competence in an academic field). Those who have are perceived to have positive aspects of the trait (i.e., are perceived to be competent in engineering) are then expected to perform better on domain-specific tasks. Conversely, those who have negative aspects of the trait (i.e., are perceived to be incompetent in engineering) are then expected to perform negatively on domain-specific tasks.

Value-Neutrality

Value-neutrality refers to the idea that scientists and engineers can and should remove contextual values from science and engineering work (e.g., gathering data, assessing claims) (Reiss & Springer, 2017). Critical race and feminist scholars argue this idea marginalizes mission-directed work (e.g., work with social justice concerns) by labeling such work as biased and lacking objectivity (Harding, 2001).

Abstract

Engineering design is often a socio-technical process that requires individual team members to combine, negotiate, and reconcile their individual differences (e.g., in technical knowledge, epistemological beliefs, identities, attitudes). Epistemological beliefs play a key role in complex problem solving, such as engineering design, since these beliefs informs how one comes to understand the problems, the types of solutions one considers, and how one selects and evaluates solutions. However, existing research suggests dominant Eurocentric epistemologies in engineering, such as beliefs that scientific and technical work must be objective and uncontaminated by one's personal values, can often work to marginalize the work and contributions of women and people of color in engineering.

The purpose of this study was to examine the ways that dominant epistemologies (i.e., Eurocentric epistemologies) in engineering are manifested (e.g., articulated, embodied, strategically wielded) by individuals in design team settings in ways that shape interactions between engineering students. A first-year design course consisting of 12 engineering design teams served as the setting for this mixed-methods study that combined a critical ethnographic approach with a quantitative network analysis to examine the role of race/ethnicity, gender, and students' engineering-related epistemological beliefs in team-based design processes.

In the ethnographic strand, guided by sensitizing concepts from Status Construction Theory, such as diffuse and specific status characteristics and four behavioral sequences (i.e., action opportunities, performance outputs, performance evaluations, and influence), I followed three focal engineering design teams during in- and out-of-classroom activities and meetings. I

also interviewed each student in the focal teams about their experiences during the project about the sources of their ideas, as well as their experiences communicating ideas to their respective teams.

In the quantitative strand, I analyzed responses to three surveys. In the first, Beginning of Term Survey, students responded to an Engineering-Related Beliefs survey containing items measuring process and product objectivity and depoliticization. In the second survey, students reported their perceptions of whether each of their teammates frequently contributed new ideas to the team's design process (i.e., contributions networks). In the third survey, students reported their perceptions of how frequently each of their teammates' ideas were enacted during the design process (i.e., enactment networks). To analyze the role of race/ethnicity, and epistemological beliefs in contributions and enactments, I utilized both descriptive analyses and a multilayer exponential random graph model (ERGM).

In the qualitative findings I described six manifestations of Eurocentric epistemologies that appeared to shape status and influence in the students' design teams. Broadly, while adherence to scientific objectivity appeared to be a strategic way that some students gained status and influence, that adherence took on various forms (e.g., communicating ideas using technical knowledge, rhetorical shifts to scientific knowledge, meticulous preparation). Moreover, I found that adherence to scientific objectivity did not always result in higher status or increased influence.

In the quantitative strand, I found no significant differences in contributions and enactments by sex. Conversely, while I found no significant differences in contributions by racial/ethnic categories, I found Black, Latino/a, and Native American/Native Alaskan students and Asian-American/Pacific Islander students were less likely to be reported as having their

ideas enacted in their teams. In addition, I found that contributions were reinforced by enactments—students who were reported as frequent contributors were more likely to have their ideas enacted. Implications for research, teaching and learning, and theory, are discussed.

Chapter 1: Introduction

Design is a core, defining component of many engineering disciplines (Dym, 1992). As a result, engineering design education has become a cornerstone of undergraduate engineering curricula (Dym, et al., 2005; Prados, Peterson, & Lattuca, 2005). A growing body of literature surrounding the ways that students understand and engage in engineering design education, and the design-related outcomes they experience, consistently points to racialized and gendered patterns of disparities in engineering education and engineering design experiences (e.g., Fowler & Su, 2018; Ro & Loya, 2015; Strehl & Fowler, 2019; Tonso, 2006). Thus, it is imperative for engineering educators and engineering education researchers to understand and address processes of marginalization in engineering design settings.

To begin, definitions of engineering design vary across the scholarly literature. Perhaps the most often-cited definition, and the definition I examine and challenge in this research, is that provided by Dym and colleagues (2005):

> Engineering design is a systematic, intelligent process in which designers generate, evaluate, and specify concepts for devices, systems, or processes whose form and function achieve clients' objectives or users' needs while satisfying a set of constraints (p.104).

Dym and colleagues (2005) argue that this definition is appropriate because it promotes a particular way of characterizing design thinking. In particular, Dym and colleagues argue that this way of defining design work and design thinking promotes design as a thoughtful, cognitively complex process. One way of describing the cognitive complexity of design is by describing the variety of factors that inform the design process. For example, Jonassen (2000) described a taxonomy of individual-level characteristics that inform how people solve ill-structured problems, such as those encountered in engineering design. Jonassen argued that epistemological beliefs are among the key individual characteristics in engineering design since design requires engineers to evaluate ideas, knowledge claims, concepts, and perspectives, and these evaluations are informed, in part, by epistemological beliefs.

Kitchener (1983) defined epistemological beliefs, sometimes referred to as personal epistemologies, as one's beliefs about the limits, certainty, and sources of knowledge. Indeed, Wenning (2009) argued that studies of epistemology largely deal with three questions: (a) what is knowledge, and what do we mean when we say we know something, (b) what is the source of knowledge, and how do we know if it is reliable, and (c) what is the scope of knowledge, and what are its limitations? In engineering and engineering design settings, existing literature suggests individual epistemological values, as reflected in the language and behaviors of engineering students are factors that constitute "good design." For example, Dym et al. describe "thinking and communicating in the several languages of design" (p. 104) as a central skill and quality that characterizes "good designers."

Dym et al. (2005) suggested that the several languages of design include "numbers used to represent discrete-valued design information" and "mathematical or analytical models used to express some aspect of an artifacts function" (p. 108). These ways of thinking, knowing, and communicating in the language of design that constitute "good design" are informed, in part, by the dominant Eurocentric epistemologies in engineering that govern individual behaviors, elevates or marginalizes particular ideas and ways of knowing, and may marginalize students of color and women in the discipline (Carter, Dueñas, & Mendoza, 2019; Cech, 2013; Harding, 2001). I contend that this definition reifies the role of Eurocentric epistemologies in engineering. Ladson-Billings (2000) described Eurocentric epistemologies in terms of beliefs in scientific objectivity (i.e., the belief that mathematics and science are the best way of knowing due to perceptions that math and science are objective). Thus, this study begins by describing the role of epistemologies in higher education, engineering education, and engineering design settings and how the dominant epistemologies in engineering education might work to marginalize students of color and women in engineering education settings.

Critical race and feminist scholars, as well as scholars studying the sociology of science and technology, have heavily critiqued the role of Eurocentric epistemologies in the sciences and engineering. Specifically, these scholars have critiqued the role that Eurocentric values, such as the elevation of scientific objectivity, value-neutrality, and depoliticization in engineering arguing that these values may operate as mechanisms of marginalization and delegitimization in research, science, and engineering (Carter et al., 2019; Cech, 2013; Harding, 2001). For example, Harding (2001) suggested the work and contributions of women in the sciences might be marginalized due to perceptions that women's science and engineering work is inherently biased and impure if it is informed by "feminist missions." The mechanisms by which Eurocentric epistemologies marginalize the work and contributions of women and people of color go by a variety of names in the scholarly literature, including *epistemological dominance* (Cech et al., 2017), and, to reflect the role of Eurocentric epistemologies in marginalizing the knowledge and perspectives of people of color, *the apartheid of knowledge* (Bernal & Villalpando, 2002) and *epistemological racism* (Scheurich & Young, 1997).

Accordingly, the first goal of this research was to understand the degree to which students, at the individual level, embody these values in their engineering work, and the ways in which Eurocentrism in engineering may marginalize students of color and women in engineering design settings specifically. The second goal was to understand how these individual level epistemologies influence design experiences. Although studies have established that epistemological beliefs play an important role in problem solving, researchers most often examine these beliefs at the individual level. Hence little is known about how these individual beliefs inform teamwork in engineering design processes. However, as Dinar et al. (2015) and Dringenberg and Purzer (2018) argue, engineering design is often a team-based, sociotechnical process that requires individual team members to combine, negotiate, and reconcile their individual differences (e.g., in technical knowledge, epistemological beliefs, identities, attitudes, dispositions). Research on design activities should thus examine the role of individual epistemologies in team-based design processes.

Moreover, Godfrey (2014) argues that engineering education often focuses on "characteristics of behaviors and practice, 'what is and what they should be' rather than the values, beliefs, and assumptions that underlie 'how they came to be'" (p. 438). In response to this critique, a central goal of this study was to examine how dominant epistemological beliefs are invoked in engineering design experiences at both the individual and team levels, and the consequences of these epistemic values for teamwork in engineering design courses. Specifically, I sought to understand how these epistemic values may operate in team-based design experiences. This research was guided by four research questions:

1. How do Eurocentric epistemologies shape the ideas that first-year engineering students consider, pursue, and discard individually and in design teams in a first-year design course?

2. How do Eurocentric epistemologies influence student interactions and status hierarchies of student design teams?
3. How do Eurocentric epistemologies shape the action opportunities, performance outputs, performance evaluations, and influence on student design teams?
4. How do Eurocentric epistemologies manifest in first-year engineering design teams in ways that might marginalize the work and contributions of students of color and women?

Overview of Methodology and Methods

In the following chapters, I describe the conceptual framework and resulting methods for examining epistemological beliefs in engineering design teams at the individual and team levels. First, I use Critical Race Theory (CRT) and the feminist critique of science to foreground race and gender and racism and sexism in engineering education. CRT establishes a set of assumptions about race and racism that I bring to this research. These tenets of CRT are (a) centrality of race and racism in American society, (b) challenge to dominant ideologies, (c) critique of liberalism, and (d) Whiteness as property. The feminist critique of science is largely consistent with this critique, focusing particularly on the ways in which science has delegitimized feminist, mission-directed work (i.e., research, engineering, and technology work laden with feminist concerns such as women's health issues) (Harding, 2001).

Second, in this study, I drew on sensitizing concepts from Status Characteristics Theory—diffuse and specific status characteristics and the four behavioral sequences (i.e., action opportunities, performance outputs, performance evaluations, and influence) it describes. These behavioral sequences provided a set of observable, measurable behaviors that could be studied in team-based engineering design settings. I utilized these concepts to understand how epistemic values might shape status in teams. Specifically, I examined how the degree to which students adhered to the dominant epistemic culture of engineering, as characterized by scientific objectivity, value-neutrality, and the ideology of depoliticization, shaped team-based approaches to engineering design. For example, if it is true that adherence to scientific objectivity, value-neutrality, and the ideology of depoliticization informs the types of ideas that are elevated on design teams, and the types of work afforded to students, I would expect to find relationships between students' beliefs and action opportunities and influence in their respective teams (i.e., research question two). Moreover, if it is true that adherence to scientific objectivity, value-neutrality, and the ideology of depoliticization differently affects students of color and women, then I would also expect to find relationships between engineering-related epistemological beliefs, race, gender, and the types of opportunities afforded to students in their respective design teams (i.e., research question three).

Finally, I used a convergent parallel mixed-methods approach (Cresswell & Clark, 2017). This convergent parallel mixed-methods approach entailed collecting both qualitative and quantitative data simultaneously, analyzing each source of data separately, and then combining them to answer the research questions in this study. Thus, I synthesized qualitative data collected through a critical ethnography with quantitative social network data from student surveys to understand how the dominant epistemic culture in engineering is embodied by individuals and teams in design settings and with what consequences for the equitable inclusion of individuals and ideas in design team activities and decisions (i.e., research question four).

Significance of the Study

This study makes contributions to the empirical literature on processes of racialized and gendered exclusion in STEM, as well as theoretical and methodological contributions to education research and research on team-based engineering pedagogies. McGee (2016) argues that hostile climates and exclusion are common experiences for students of color in STEM disciplines that affect their academic and social experiences and behaviors. Other scholars have linked the negative experiences for students of color and women in engineering to the dominant epistemologies of the discipline, arguing that dominant epistemologies in engineering may marginalize students of color (Cech et al., 2017). However, this study goes beyond individual experiences of racialized and gendered hostilities to examine how dominant, ubiquitous values in engineering shape the engineering work students produce, particularly in team-based design settings.

Existing scholarship on the role of Eurocentric epistemologies in shaping engineering work has been largely theoretical, positing mechanisms by which Eurocentric epistemologies marginalize the work and contributions of people of color and women in the sciences. Where scholars have discussed explicit manifestations and consequences of Eurocentric epistemologies (e.g., Cech et al., 2017), empirical research has largely focused on individual experiences of marginalization, rather than the role of Eurocentric epistemologies in interactions between peers, such as those that occur in team-based engineering design settings. As noted, and discussed further in Chapter 2, engineering design is often a sociotechnical process requiring engineering students to interact to solve engineering problems. In this study I examine the ways that dominant epistemologies (i.e., Eurocentric epistemologies) in engineering are manifested (e.g., articulated, embodied, strategically wielded) by individuals in team settings in ways that shape interactions between engineering students. Moreover, I examine the ways Eurocentric epistemologies shape the ideas individual engineers and engineering teams consider, pursue, and discard in engineering design settings.

This study thus makes a methodological contribution to engineering education and educational research broadly by demonstrating a new approach to studying nested social networks. In the quantitative networks strand of this study, I examined the engineering ideas students put forth to their teams (i.e., idea contributions), the ideas teams pursued (i.e., idea enactments), and the role of Eurocentric epistemologies, race/ethnicity, and gender in shaping how students negotiated idea contributions into idea enactments. Traditional approaches to analyzing multiple relationships in networks in education studies entail analyzing the two relationships separately (i.e., modeling contributions and then modeling enactments) and then comparing the two models to draw conclusions. Instead, I used the multilayer exponential random graph model (i.e., multilayer ERGM), a novel approach to analyzing multiplex networks—networks where ties represent two or more relationships (Chen, 2019), marking the first time this approach has been used in a network analysis in an education research setting.

Finally, this study makes theoretical contributions to research on racialized and gendered power dynamics in interaction in engineering education that is potentially applicable in broader STEM education settings. Pawley (2019) notes that engineering education research has traditionally used limited and exclusionary methods, such as studying gender as "distinct, binary, and enduring categories" (p. 15), for studying race/ethnicity and gender, and by extension racism and sexism in the discipline. In Chapter 2, I discuss various conceptualizations of race and gender that informed the data analysis process in this study (e.g., race and gender as variables, race and gender as socially constructed, race and gender as ideologies). Throughout the findings chapters, I return to these conceptualizations to discuss both implications for understanding the findings herein, as well as how these varying conceptualizations might challenge interpretations of existing findings on the experiences of students of color and women in engineering.

Chapter 2: Literature Review

This research seeks to understand how dominant epistemic values of engineering appear in engineering design at both the individual and team levels. In this chapter, I review relevant literature on epistemological beliefs, and describe how existing literature shapes the conceptual framing of this research, as well as the methodology and methods I used to answer my research questions.

I begin this review of the theoretical and empirical literature by discussing (a) the role of personal epistemologies in higher education and (b) how the literature on personal epistemologies shapes the theoretical perspective and methodological approaches of this study. Second, drawing on findings that epistemological beliefs are both domain-general and domain-specific, I review the literature on epistemological beliefs in engineering education specifically. Third, I establish the importance of examining racialized epistemologies in engineering and the use of a Critical Race Theory (CRT) in framing research on racialized epistemologies. Finally, I discuss components of Status Characteristics Theory (SCT) that can be used to understand how particular behaviors can be the result of racially biased epistemologies in engineering. I conclude this chapter with an integrated framework for studying the role of dominant epistemologies in engineering design teams.

The Role of Epistemological Beliefs in Learning in Higher Education

Epistemological beliefs, which encompass students' beliefs about knowledge, the nature of knowing, and sources of knowledge (Hofer & Pintrich, 1997; Hofer, 2001; Kitchener, 1983) have received considerable scholarly attention in research on teaching and learning in higher education. Over the past several decades, a consistent body of literature has established the important role of individual epistemological beliefs, also referred to as personal epistemologies, in higher education settings, tying individual epistemologies to academic behaviors such as learning strategies and studying (e.g., Heiskanen & Lonka, 2012; Hofer & Pintrich, 1997; Rodriguez & Cano, 2007), cognitive skills such as problem-solving (e.g., Faber & Benson, 2017; Jonassen, 2000), non-cognitive factors like motivation and self-regulation (e.g., Buehl & Alexander, 2005), and academic performance (e.g., Barger et al. , 2016). These studies of epistemological beliefs are important in the context of this research for several reasons.

First, these studies established the theoretical basis on which empirical studies of epistemological beliefs are based. Second, these studies established that epistemological beliefs may evolve because of students' experiences in college. Third, existing research has established that epistemologies can be both domain-general and domain-specific, though the view that epistemological beliefs are, and as a result should be measured as, domain-general holds a tenuous position in the literature. For example, Buehl and Alexander (2001) argued that while individuals may hold domain-general beliefs about knowledge and knowing, beliefs about knowledge and knowing might vary in particular academic settings (e.g., engineering) and based on particular forms of knowledge (e.g., engineering knowledge). Indeed, DeBacker and colleagues (2008) examined three widely used, self-report measures of epistemological beliefs and, consistent with arguments from Buehl and Alexander (2001), "failed to support the view of epistemic beliefs as domain-general" (p. 301). This suggests a need to understand students' epistemological beliefs in the specific domain of engineering and perhaps in engineering design settings more specifically. Additionally, studies of epistemological beliefs in higher education settings have identified a number of critical issues for empirical work in this area. In the next section, I discuss each of these as they relate to this research.

Conceptions of Epistemological Beliefs

Richardson (2013) divides theories of epistemological beliefs into two broad categories: (1) "stage" theories, which assume that epistemological beliefs are unidimensional and develop along a fixed sequence of distinct epistemological stages, and (2) "non-stage theories," which assume that students develop beliefs about knowledge and knowing "along one or more continuous dimensions" (p. 192). These two broad categories also align with methodological approaches to studying personal epistemologies in educational research.

Early research on epistemological beliefs in educational settings were generally based on qualitative work and resulted in an understanding of personal epistemologies as unidimensional, and stage based (Richardson, 2013). Perhaps the most popular such theory, and the theory most prevalent in engineering education research is Perry's scheme (King & Magun-Jackson, 2004). Perry (1970) conducted open-ended interviews with male Harvard University students and described changes in their thinking processes over the course of their collegiate experiences. Perry posited that epistemological development happened over nine positions, grouped into four categories, representing increasingly advanced ways of thinking: (a) dualism, (b) multiplicity, (c) relativism, and (d) commitment (Richardson, 2013). Perry's stage-based scheme served as the basis for other theories of epistemological development and has been used both to categorize students in terms of intellectual development as well as design and organize strategies for supporting students' epistemic development (e.g., Evans, 2011; King & Magun-Jackson, 2004).

Later research adopted the view that epistemological beliefs are multidimensional systems of beliefs (e.g., Ladson-Billings, 2000; Schommer, 1990). According to Hofer (2001) and King and Magun-Jackson (2004), Schommer (1990) was the first to propose that epistemological beliefs are multidimensional systems of independent beliefs about knowledge and knowing rather than a singular set of beliefs at particular stages of development. In an effort to develop the first quantitative measures of epistemological beliefs, Schommer posited that these beliefs varied along five bipolar dimensions, including (a) simple knowledge (i.e., the degree to which one believes knowledge is simple rather than complex), (b) omniscient authority (i.e., the degree to which one believes knowledge is handed down by authority rather than derived from reason), (c) certain knowledge (i.e., the degree to which one believes knowledge is certain rather than tentative), (d) innate ability (i.e., the degree to which one believes the ability to learn is innate rather than acquired) and (e) quick learning (i.e., the degree to which one believes learning is quick) (Hofer, 2001; King & Magun-Jackson, 2004; Schommer, 1990).

The Schommer framework and subsequent instrument served as the foundation for several instruments designed to measure epistemological beliefs. For example, the Engineering Related Beliefs Questionnaire (ERBQ) developed by Yu and Strobel (2011) and modified by Faber and Benson (2017) drew on Hofer and Pintrich's (1997) framework. Indeed, of the 13 instruments measuring epistemological beliefs across a variety of domains (e.g., science, physics, mathematics) that followed Schommer's (1990) instrument listed by Ozmen and Ozdemir (2019), at least half drew on the hypothesized dimensions proposed by Schommer. These instruments often measure epistemological beliefs along a set of bipolar dimensions, where, for example, Hofer and Pintrich's *certainty of knowledge* dimension ranges from beliefs that knowledge is fixed, absolute, and unchanging on one extreme to beliefs that knowledge is fluid, contextual, and constructed on the other (Faber & Benson, 2017; Hofer & Pintrich, 1997).

This dissertation study seeks to examine the degree to which students adhere to the claims about knowledge and knowing associated with a particular epistemological perspective – the dominant epistemological perspective in engineering, which I discuss in a later section.

Domain-Specific Epistemological Beliefs

Early research examining epistemological beliefs viewed them as domain-general, meaning that these beliefs were generally characterized as fixed across contexts, such as academic disciplinary settings. Examples of domain-general models of epistemological beliefs include Perry's Scheme (described above), *Women's Ways of Knowing* described by Belenky, Clincy, Goldberger, and Tarule (1986), and the *Epistemological Reflection Model* described by Baxter Magolda (1992). These theories and models of epistemological beliefs and development are limited in that, as Buehl and Alexander (2001) argue, they do not recognize both the general beliefs people hold about knowledge and knowing, as well as the nature of knowledge and knowing in specific contexts (such as academic fields of study).

Later studies of epistemological beliefs have examined epistemological beliefs in specific academic domains (Faber & Benson, 2017; Hofer, 2006). These studies posit that beliefs about knowledge reflect, in part, the domain in which the knowledge is situated. In this study, I adopt the view of "domains" described by Buehl and Alexander (2001). That is, a domains refer to "recognized fields of study associated with academic realms" (p. 401). Several studies examine engineering-related epistemological beliefs in engineering education settings and support the claim that differences in engineering-related epistemological beliefs result in various approaches to problem solving in engineering specifically.

Conceptualizations of domain-specific epistemological beliefs largely align with Hofer and Pintrich's (1997) framework, which was a modification of Schommer's (1990) framework.

Specifically, Hofer and Pintrich argued personal epistemologies consist of beliefs about the nature of knowing (i.e., certainty of knowledge, simplicity of knowledge) and beliefs about the nature of knowledge (i.e., source of knowledge, justification for knowing), but they argued that Schommer's dimensions of quick learning and innate ability factors are outside of the scope of epistemological beliefs, instead describing them as "peripheral beliefs about learning, instruction, and intelligence" (p. 115). Hofer and Pintrich argued that "a belief about what knowledge is and how it can be described is not the same as how quickly one might go about learning" (p. 109), thereby separating learning beliefs from beliefs about knowledge.

At least two instruments for measuring domain-specific engineering-related epistemological beliefs are guided by Hofer and Pintrich's four-dimensional framework. Carberry and colleagues (2010) developed the Epistemological Beliefs Assessment for Engineering (EBAE), a modification of the Epistemological Beliefs Assessment for the Physical Sciences (EBAPS). Carberry et al. validated their instrument using a sample of 43 first-year engineering students, a sample size the authors acknowledge falls well short of established minimum sample sizes for their validation techniques (i.e., principal components analysis and confirmatory factor analysis). Perhaps as a result, the study did not present the factor analysis results. Nonetheless, Carberry et al. argued for a 13-item measure reflecting the four constructs in Hofer and Pintrich's (1997) framework: (a) certainty of engineering knowledge (3 items), (b) simplicity of engineering knowledge (3 items), (c) source of engineering knowledge (3 items), and (d) justification for engineering knowledge (4 items).

Yu and Strobel (2012), who defined epistemological beliefs as beliefs about the nature of knowledge and the process of knowledge development, developed the 22-item Engineering Related Beliefs Questionnaire (ERBQ), again based on Hofer and Pintrich's (1997) four-dimensional framework. Yu and Strobel conducted focus groups with graduate students and faculty members to establish content validity but offered no statistical support for the validity of the instrument. Faber and Benson (2017), who used the ERBQ in a study of engineering epistemological beliefs in open-ended problem solving, reported that one of the factors in the ERBQ—simplicity of knowledge—had a Cronbach's alpha of .48, which is well below established cutoff values for acceptable internal consistency[1]. Thus, neither of these instruments measuring engineering-related epistemological beliefs has been thoroughly validated in a study published in the empirical literature.

Jonassen (2000) viewed epistemological beliefs as an important aspect of individual problem solving, particularly during complex problem solving (i.e., engineering design). According to Jonassen, individual beliefs about knowledge and knowing (i.e., epistemological beliefs) inform how individuals approach problems, including how one comes to understand the problem (i.e., problem definition), the types of solutions one considers, and how various solutions are selected and evaluated (Hofer, 2001; Jonassen, 2000; Kitchener, 1983). Thus, the need for further research on the role of epistemological beliefs in the context of complex problem solving, such as engineering design, remains.

To this end, Faber and Benson (2017) integrated quantitative and qualitative methods to study the role of engineering-related epistemological beliefs, epistemic motivation, and epistemic cognition in the context of open-ended problem solving. After dropping some items and factors due to concerns about reliability (described above), Faber and Benson (2017) used two constructs from the ERBQ (i.e., Source of Knowledge and Certainty of Knowledge) to assess the

[1] A coefficient alpha greater than the often-cited threshold of 0.70 is generally characterized as acceptable. However, some scholars critique the use of *rules of thumb* in statistical analyses, and authors often cite factors for the continued use of scales that fail to meet this threshold in scale validation studies (Taber, 2018). For example, Taber (2018) cites studies that continued to use scales that did not meet this threshold due to issues of sample size.

relationships between engineering-related epistemological beliefs and approaches to problem solving. Faber and Benson's results suggested engineering students' epistemological beliefs and motivations affect strategies students employ when solving problems. For instance, students with less constructivist beliefs (i.e., the tendency to believe that knowledge comes from authority, and that engineering knowledge is absolute), were more likely to believe that problems had a single correct answer, thereby affecting their approach to solving open-ended problems.

Other scholars have used qualitative approaches, typically utilizing think-aloud protocols and interviews, to examine the relationship between epistemological beliefs and problem solving in engineering. For example, Gainsburg (2015) studied students' beliefs about the role of mathematics in engineering problem solving. Similarly, although McNeill and colleagues (2016) were fundamentally interested in the role of engineering-related epistemological beliefs in problem solving, they used domain-general measures of epistemic beliefs (the Reasoning about Current Issues Test provided by P. M. King, n.d.) to draw a sample that maximized the variation in epistemological beliefs. Although these studies did not examine the role of engineering-related epistemologies, Gainsburg (2015) and McNeill and colleagues (2016) used qualitative research methods (e.g., interviews, think-aloud protocols, observations) to study engineering students' epistemological beliefs in engineering problem-solving. Amongst other findings, both Gainsburg (2015) and McNeill and colleagues argued that epistemological beliefs may depend on contextual influences (e.g., in the workplace vs. the classroom in McNeill et al.), supporting Hofer's (2006) argument that researchers should consider both academic (e.g., engineering) and judgment (e.g., personal taste, morality, beliefs about the natural world) domains when examining students' epistemological beliefs.

While a few studies suggest epistemological beliefs play a role in individual problem solving (Faber & Benson, 2017; Jonassen, 2000), they leave open the question of how these individual beliefs inform team-based problem solving (e.g., design) processes. To that end, in this research, I expand on existing literature by studying how epistemologies inform not only how individual engineers engage in individual design processes, but how these epistemologies inform team processes and behaviors.

Epistemological Beliefs Over Time

Studies of epistemological beliefs in higher education broadly suggest that students' epistemologies may not be static beliefs, but rather develop and evolve over time as a result of their experiences in higher education (Rodriguez & Cano, 2007; Wise et al., 2004). Scholars like Perry (1970) and Baxter Magolda (1992) attempted to describe, theoretically and empirically, the development of individual epistemological beliefs. There is some debate in the empirical literature on engineering students' epistemological beliefs about whether these beliefs are relatively static or evolving over the course of the undergraduate education experience. Some studies suggest that engineering specific beliefs are malleable during the engineering education experience (Barger et al., 2016). A four-year longitudinal study by Wise et al. (2004), however, found that "little intellectual development happens during the first two years of an engineering undergraduate's studies" but is followed by a "sudden burst of growth in the fourth year" (p. 109). Wise and colleagues attributed these patterns of development to the engineering science model of curriculum, wherein first- and second-year course position instructors as "Authorities" (capital A specified by the authors) on engineering knowledge, while fourth-year courses, laden with team- and project-based learning experiences, position students as co-constructors of knowledge.

These diverging findings inform a critical methodological decision I describe in the third chapter: How often should I measure students' epistemological beliefs in order to capture an accurate representation of students' engineering-related epistemologies? As I describe in the next chapter, the setting of this study is a first-year engineering course. If the findings of Wise and colleagues (2004) are correct, then the epistemological beliefs of participants in this research are likely to be relatively stable. However, the setting is also a design project course, in which Wise and colleagues argued epistemological beliefs might evolve as students co-construct knowledge in teams. I considered both arguments as I developed the study design, which I describe in the next chapters.

Issues in Studying Epistemologies

Studies of epistemological beliefs identified several methodological issues in measuring personal epistemologies in educational research. For example, DeBacker et al. (2008) noted that while it is "intuitively appealing to believe that measures of epistemic beliefs that are more domain- or context-specific would yield higher internal consistency" (p. 303), existing measures of domain-specific epistemologies have yielded low internal consistency (e.g., Hofer, 2000; Buehl et al. 2002 as cited in DeBacker et al.). As noted, the construct Simplicity of Knowledge in the Engineering Related Beliefs Questionnaire yielded low internal consistency in Faber and Benson's (2017) study.

Other issues arising in the literature involve the dimensionality of epistemological beliefs. How many dimensions are there? Are these dimensions consistent across time and domain? Schommer's (1990) foundational research, which posited five independent dimensions of personal epistemologies was later modified since factor analysis in the original study, and subsequent replications of the work, suggested a four-factor structure (Paulsen & Wells, 1998;

Schommer, 1990). That is, in both Schommer's (1990) original work, and the replication examining the survey (Schommer et al. 1992), items related to authority (i.e., omniscient authority) did not load onto a single factor. Future research on epistemological beliefs must be cognizant of these open questions.

Finally, a critical issue in studies of epistemological beliefs and epistemological development, both in the domain-general and domain-specific sense, lies in understanding how epistemological views are obtained. For example, Cech and Sherick (2015) argue that engineering-specific ideologies and epistemologies are the result of at least two processes: professional socialization—the process by which students learn the beliefs and values of the culture of engineering—and the structure of the engineering curriculum itself. Indeed, Wise et al. (2004) similarly argue that the curricular structure in engineering positions students as receptors of knowledge, values, and beliefs from authority figures (e.g., faculty), which is particularly important since Cech and Sherick (2015) argue many faculty in engineering lack the pedagogical training needed to weave socio-cultural contexts into engineering education. While these arguments are consistently leveled in the literature, empirical analyses of how students may embody the dominant culture of engineering themselves is a critical area of research this study seeks to address.

Engineering Epistemology: Connections to Eurocentrism

The National Engineering Education Research Colloquies (EERC) (2006) recommended research on "engineering epistemologies," which, according to Pawley (2009) entails examining engineering beliefs, values, knowledge, and ways of thinking, knowing, and doing, as a key area for future research for defining the discipline. Research on engineering epistemologies entails addressing what Yu and Strobel (2012) described as the "social practices view of epistemology," which describe ways of being a member in an epistemic culture of engineering, “such as observing from a particular point of view, representing data, persuading peers, engaging in special discourse, and so forth, locally defining knowledge” (p. 3).

The endeavor to describe the dominant epistemic culture of engineering has taken many forms. For example, early studies of college students’ epistemological beliefs juxtaposed the epistemological beliefs of students across fields of study in order to develop relative epistemic profiles of individual disciplines. Existing studies of disciplinary differences in epistemological beliefs have described engineers as having more naïve beliefs about the certainty of knowledge than students in the humanities (Paulsen & Wells, 1998), suggesting that engineers are more likely to believe knowledge is objective, neutral, and fixed, rather than rather than subjective or tentative.

Other scholars have described characteristics of the epistemic culture of engineering in terms of beliefs about the nature of engineering work. For example, Kant and Kerr (2018) describe engineering in terms of the *mythical engineer*, “typically, a man...personally interested in ‘how things work’ and *making stuff*: homo faber rather than homo rationalis” (Kant & Kerr, p. 18). The mythical engineer, according to Kant and Kerr, is similar to the mythical scientist, drawing on prescribed heuristics—the “engineering method”—to produce concepts capable of being utilized in technical artifacts. The mythical engineer, then, is utilitarian in approach, using available resources to produce artifacts that are useful and that produce some benefit or desired change. These descriptions of the dominant, if not at times mythical, epistemologies in engineering as emphasizing and valorizing objectivity, neutrality, and depoliticization are commonly used to describe scientific epistemologies (Grincheva, 2013; Walton & Zhang, 2013; Wenning, 2009). This extension of scientific epistemologies to engineering are unsurprising given that engineering is often characterized as “applied science” (Norström, 2013; Shaw, 2001). However, these descriptions are also tenets of what Ladson-Billings (2000) describes as Eurocentric epistemologies.

Rooted in Enlightenment era philosophical and intellectual thought, Eurocentric epistemologies establish scientific knowledge as the foundation for knowledge and knowing and “reasoned that everything from human biology to the art of governing could and should imitate science” (Ladson-Billings, 2000, p. 259). Science, according to the Eurocentric view, is impartial, value-neutral, objective, and represents the best method for truth-seeking (Ladson-Billings, 2000). Objectivity and value-neutrality are closely related concepts underlying Eurocentrism in science and engineering. Grincheva (2013) argues objectivity “refers to employment of specific ways of observation or experimentation” for knowledge production (p. 2). Scientific objectivity is defined in at least two different forms: (a) product objectivity—the idea that the product of science and engineering work (i.e., laws, theories, observations) is objective and represents “accurate representations of the world”, and (b) process objectivity—the idea that scientific processes (e.g., methods of observation and measurement, reasoning) are absent normative commitments and individual values (Reiss & Springer, 2017). These concepts are closely related to the idea of value-neutrality and depoliticization in that they represent valorized ideals that govern individual and team-level behaviors in science and engineering (Cech et al., 2017; Grincheva, 2013; Reiss & Springer, 2017).

Indeed, Cech (2013) described the epistemic culture of engineering as valorizing depoliticization, defined as the belief that engineering work is technical, should be carried out *objectively*, and should be devoid of social bias. As a result, epistemologies grounded in social (e.g., racialized, gendered) experiences are delegitimized insofar as they do not adhere to "culturally and institutionally valorized" dominant epistemologies (Cech et al., 2017). As Carter, Dueñas, and Mendoza, (2019) write, depoliticization—the adherence to logical positivism grounded in Eurocentric scientific epistemologies—"sanctions the separation of social justice concerns from engineering work which may lead students in engineering environments to suppress discussions of conflicting moral values and perspectives" (p. 72).

Historically, the Eurocentric epistemologies have been the foundation on which racial inequality itself is based (Carter et al., 2019; Ladson-Billings, 2000, p. 259). Scholars have characterized the ways in which Eurocentric epistemologies created and reified social (e.g., racial/ethnic, gender) hierarchies and racism/sexism in Western society (e.g., Carter et al., 2019). In particular, the mechanisms by which Eurocentric epistemologies operate in engineering contexts have been variously described in the engineering education literature. Cech and colleagues (2017) used the term *epistemological dominance* to describe how Eurocentric perspectives, with their basis in mathematics and science, "monopolize truth claims" and disadvantage students who enter science and engineering spaces with alternative or marginalized epistemologies. Students who bring marginalized epistemologies to engineering contexts are then required to adopt strategies to negotiate the differences between their own epistemological perspectives and the more highly valued Eurocentric view common in the discipline (Carter et al., 2019; Cech et al., 2017).

The role of Eurocentric epistemologies in academia, and the effects of Eurocentric epistemologies have on the experiences of people of color in academia (e.g., researchers in the academy, students in engineering) have been variously described in the literature. For example, Scheurich and Young (1997) referred to epistemological racism—the idea that *research* epistemologies – "not our use of them, but the epistemologies themselves" (p. 4) – are racially biased. According to Scheurich and Young, racially biased epistemologies have the negative consequence of delegitimizing epistemologies and research that are based in non-Eurocentric traditions (e.g., Black American, Indigenous epistemologies), creating what Bernal and Villalpando (2002) call an *apartheid of knowledge*. This apartheid of knowledge "marginalizes, discredits, and devalues the scholarship, epistemologies, and cultural resources of faculty of color" (Bernal & Villalpando, p. 169), and is deeply engrained in American higher education.

Just as critical race scholars have critiqued the role of Eurocentrism in the dominant epistemologies of science and engineering, so too have feminist scholars, who note the ways in which dominant epistemologies marginalize women in science and engineering disciplines. Harding (2001) argued that Eurocentrism, which values "the 'disenchanted' material world, cultural neutrality, rational processes, objective decisions, the interchangeability ('equality') of their central actors, and other features" (p. 292) is pervasive in the modern sciences, often forming the basis of what constitutes real or good science. According to Harding (2001), and consistent with Cech (2013) and Carter et al.'s (2019) arguments about the ideology of depoliticization in engineering, these Eurocentric values sanction the separation of feminist concerns from "real science." That is, research, as well as engineering and technology development, that is guided by "feminist missions" (e.g., women's health issues, technical developments to serve women's needs) are deemed "damagingly biased" since these "cultural (i.e., feminist) interests" are associated with "a damaging lack of objectivity" (Harding, 2001, p. 297), thereby marginalizing feminist work in science, engineering, and technology.

Moreover, other scholars studying the role of Eurocentrism note the role of Eurocentric values (i.e., objectivity, value neutrality) in shaping the experiences of people living at the intersections of racism and sexism. For example, Collins (1991) articulated a Black Feminist epistemology, wherein core tenets describing the processes by which knowledge and meaning is constructed and utilized diverge from Eurocentric and masculinized values related to scientific objectivity and value-neutrality. For example, in the Afrocentric Feminist epistemological perspective, “knowledge emerges in dialectical relationships” and “meaning is a product of dialogue between and among individuals” (Ladson-Billings, 1995, p. 473). Moreover, the Afrocentric Feminist epistemological perspective describes the role of caring, which entails both affective relationships between individuals, as well as “a greater sense of commitment to what scholarship (or in this case, engineering design) can mean in the lives of people” (p. 474). Afrocentric Feminist epistemologies also foreground personal accountability, which expressly rejects the notion of objectivity as it relates to knowledge claims (Ladson-Billings, 1995). Just as this system of thinking (e.g., dialogue, ethic of care, personal accountability) is useful for generating and utilizing knowledge in academic settings (Ladson-Billings, 1995), this epistemological frame is needed in design settings. It should be noted, however, that the goal of my study is not to disentangle processes of marginalization at the intersection of race and gender (i.e., to distinguish epistemological racism from epistemological sexism). Rather, I examine the role of a particular perspective—the Eurocentric perspective—in teamwork in engineering.

The process of marginalizing, discrediting, and devaluing non-Eurocentric epistemologies is particularly important since, as Duncan (2002) argues, marginalized populations possess values and attitudes that require explanation because they deviate from dominant, privileged groups. For example, Brayboy (2006) argues Eurocentric thinkers value systematic knowledge that is capable of meeting productivity needs, often dismissing epistemologies that diverge from systematic, utilitarian ways of thinking and knowing. This Eurocentric way of thinking often appears in the engineering design curricula where, as Dym and colleagues (2005) note, engineering design education has shifted over the past several decades to include industry partners that position students to solve real-world, industry related problems. That is, design education is framed and implemented around its importance for meeting productivity needs in industry.

Still, non-Eurocentric epistemologies do not necessarily diverge completely from the Eurocentric frame. Other epistemological frames, for example, similarly value utilitarianism. However, the system of thinking on which utility is obtained and assessed in non-Eurocentric epistemologies might differ from that of the Eurocentric epistemologies. For example, Brayboy (2006) argues "tribal philosophies, beliefs, customs, traditions, and visions for the future" (p. 429) are critical forms of knowledge in Indigenous epistemologies. These critical forms of knowledge form a system of thinking that, in complement with "book knowing," are useful for meeting ends such as social justice goals (Brayboy, 2006). These forms of knowledge and ways of knowing in Indigenous epistemologies are useful for meeting social justice means (e.g., tribal sovereignty, tribal autonomy) (Brayboy, 2006), as well as critical aspects of Indigenous students' learning in engineering (Cech et al., 2017).

Scheurich and Young (1997) and Bernal and Villalpando (2002) acknowledged that the racially biased, Eurocentric epistemologies that dominate education research marginalize the epistemologies and research of scholars of color in academia. Along the same line, an emerging line of research has examined the role of Eurocentric epistemologies in marginalizing students of color in engineering education. For example, Cech and colleagues (2017) interviewed Native American students in science, engineering, and health-related fields and argued that dominant, Eurocentric epistemologies in these disciplines delegitimize Native epistemologies and require students to participate in practices that challenge their own (i.e., Indigenous) ways of knowing.

A number of scholars have examined, theoretically and empirically, the consequences of epistemological dominance and racism in engineering, noting the ways that dominant students respond to Eurocentric epistemologies and racism in engineering at the individual level. Existing literature suggests students adopt several strategies for navigating the conflicting epistemic culture of engineering (Carter et al., 2019). For example, Carter and colleagues note that native students might selectively add elements of Eurocentric epistemologies to their base of culturally relevant epistemologies in response to epistemic dominance in engineering. This literature suggests that students might be aware, either implicitly or explicitly, of the role of dominant epistemologies in their experiences in engineering.

While the literature describing the role of students' epistemological beliefs—called personal epistemologies—demonstrates that these beliefs inform problem solving processes at the individual level (e.g., Faber & Benson, 2017; Jonassen, 2000), less is known about the way these beliefs inform team-based engineering design processes. In the following sections, I draw on Critical Race Theory and Status Characteristics Theory to describe an integrated framework for examining how epistemological dominance may marginalize engineering students of color and women in first-year design teams.

Race and Gender Matters in Engineering

The literature on processes of marginalization for students of color and women in engineering is vast, with findings that consistently point to experiences of racialized and gendered hostility, exclusion, and marginalization in educational settings (Fowler & Su, 2018; Strehl & Fowler, 2019; Wolfe & Powell, 2009). The study of race, and by extension, the racialized experiences of students of color in science, technology, engineering, and mathematics (STEM) education is not a new scholarly endeavor in educational research. Persistent disparities in degree attainment in engineering for students of color in STEM disciplines have rendered the study of race in these educational contexts paramount for broadening participation, closing achievement gaps, and addressing the social, political, and economic needs of the future (Harper, 2010; Palmer, Maramba, & Dancy II, 2011).

While the literature on racial disparities in persistence and attainment of students of color is abundant (National Science Foundation, 2016), McGee (2016) argues that hostile climates and exclusion are common experiences for students of color in STEM and affect their academic and social experiences and behaviors. Few studies, however, have examined the role of race in the quintessential work that engineers do—engineering design. While some studies allude to the importance of "diverse perspectives" in design processes (e.g., Dringenberg & Purzer, 2018), diversity is typically broadly defined, and racial diversity is rarely, if ever, examined explicitly. In the next sections of this review, I discuss a conceptualization of race and the role of racialized epistemologies that is grounded in Critical Race Theory (CRT).

Defining and Conceptualizing Race

O'Connor and colleagues (2007) argue that, while the literature on racial gaps in educational experiences and outcomes routinely invokes race, race has been undertheorized in the education literature. In a study of conceptualizations of race in health research, Corbie-Smith et al. (2008) acknowledged a debate regarding "whether race is a biological construct, a social construct, or something in between" (p. 2008), discussing two conceptualizations of race: (a) *race as biology* and (b) *race as a social construct*. The view of race as a biological construct is neither new nor unique to health research. Indeed, in many ways, *race as biology* is rooted in the very same Eurocentric epistemologies that I discussed in previous sections. For example, Carter et al. (2019) argued that the development of science during the Enlightenment period coincided with attempts to explain racial differences and justify resulting racial hierarchies using (perceived) *objective* scientific methods for classification and examination in empirical (though pseudo-scientific) research. Carter et al. (2019) described a host of popular pseudo-scientific methods for classifying human beings and determining racial differences—craniometry (i.e., measuring skulls to predict intelligence), evolutionary theory (i.e., the belief that non-Whites were less evolved than Whites), eugenics (i.e., improving human beings through selective reproduction). All of these approaches were grounded in the Eurocentric principle that the *truth* underlying racial differences (a) exists and (b) could be known and proven through objective, scientific methods (Carter, 2019).

O'Connor et al. (2007) argues that *race as biology* has been disproven in the biological and anthropological literature, particularly insofar as *race as biology* has served as a proxy for "something else" (e.g., culture). They argued that two dominant conceptualizations of race have informed educational research on racial differences and racialized experiences in empirical literature: (a) race as culture and (b) race as a variable. Research in the *race as culture* tradition views race as a collection of norms and beliefs that govern the behaviors of individuals within racial groups. Research in this tradition established Whites as the normative referent (O'Connor et al., 2007) and attempted to explain racial differences by understanding select cultural norms, beliefs, and behaviors that diverged from the normative reference group (i.e., Whites). Similarly, much of the engineering education literature adopts *race as a variable,* wherein race is viewed as a broadly defined, colloquial term, adhering to broad racial categorization schemes (e.g., Black or African American, Asian American/Pacific Islander) (Pawley, 2019). This occurs despite the fact that race has been defined, conceptualized, and measured in a multitude of ways in the theoretical and empirical literature on race and racism.

O'Connor et al. (2007) argued that a growing group of scholars, seeking to disrupt the normative supremacy of Whiteness, sought to "highlight the productive qualities, codes, styles, and orientations" of Black children. Similarly, O'Connor et al. (2007) described research on racial disparities and racialized experiences as following the *race as a variable* tradition. This tradition has been similarly critiqued for its typical practice of collapsing racial categories for comparison to White reference groups (O'Connor et al., 2007).

According to Corbie-Smith et al. (2008), researchers that view *race as a social construct* often pointed to social factors that were associated with race to explain social issues (i.e., health disparities). The view of race as a social construct focuses attention away from the categories described in the *race as variable* tradition toward the economic, political, social, and ideological consequences of race and, by extension, racism (Bonilla-Silva, 1999). While this view may be more suitable for unmasking and addressing social factors related to racial disparities and differences, the view of race as a social construct may not offer a straightforward means by which to conceptualize race in empirical analysis. For example, Solomos and Back (2000) contend that *race*, when viewed as a social construct, "is contested and fought over" since this implies that race has a political meaning, and "the meaning of terms like 'black' are struggled over" (Solomos & Back, 2000, p. 8). Conceptualizing race as a social construct, then, cannot stop at racial categorization, but should examine "the process by which race is constructed as a social and political relation" (Solomos & Back, 2000, p. 8). Such an examination is beyond the scope of this work; instead I articulate a set of propositions that establish these social and political relations as assumptions of the conceptual framework for this study.

While all of these conceptualizations of race are, in some ways, interconnected, in this study, I adopt the view of *race as ideology*. This view of race establishes race, and by extension racism, as a system of values, beliefs, and practices—even those which have been stripped of their explicit, formal, and codified manifestations of racial powers (Crenshaw, 1995)—that justifies social structures and hierarchies that benefits whites and marginalizes people of color (Lopez, 2003; Bonilla-Silva, 2005; Bonilla-Silva, 2003). In the next section, I draw on CRT to explicate this system of beliefs and practices, as well as how dominant epistemologies contribute to the ways in which racial ideologies organize action in engineering and engineering design.

Defining and Conceptualizing Gender

Just as the ways that the scholarly literature conceptualizes race and by extension racism varies, so too does the scholarly literature on sex and gender. For example, in the previous section I described how *race as a variable* articulates race as a set of broad racial categories (e.g., Black or African American, Asian American/Pacific Islander). Similarly, Pawley (2019) argued that studies in engineering education research have overwhelmingly viewed gender as mutually exclusive binary social categories (i.e., man and woman). This view of gender is somewhat akin to a combination of the view of *gender as a variable* and *gender as biology* (i.e., similar to *race as biology* and *race as a variable* described above). That is, recent literature has critiqued the use of binary gender variables wherein sex is conflated with gender, and thus sex, a biological trait assigned at birth (i.e., male, female), is conflated with gender (i.e., man, women) (Nicolazzo, 2015). This conflation also entails the problematic erasure of trans* individuals from discussions of gender in empirical analyses (Nicolazzo, 2015).

Other studies of gender conceptualize gender in terms of the norms that govern social behaviors (i.e., *gender as a social construct* if you will). The conceptualization of gender as a socially defined construct takes many forms. For example, Butler (1988) described a perspective wherein gender is not a fixed identity, as is implied in the *gender as a variable* perspective above, but is instead “understood through the mundane way in which bodily gestures, movements, and enactments of various kinds constitute the illusion of an abiding gendered self” (p. 519). Gender, then, is understood as a complex interplay of biological sex (e.g., male), identity (e.g., man), and expression (e.g., masculine) (Nicolazzo, 2015). That is, social behavior is governed by normative relationships, wherein male implies man implies masculine, and female implies woman implies feminine.

Of course, the degree to which individuals adhere to social norms governing gendered behaviors is also another way that gender is conceptualized in the empirical literature. For example, Mahalik and colleagues (2003) developed the Conformity to Masculine Norms Inventory (CMNI), measuring the degree to which individuals meet behavioral expectations for what are considered masculine behaviors, such as constraining emotional responses, exerting power over women, or the desire to win. Importantly, masculinity and femininity are defined as much by observable social behaviors (i.e., what one visibly does) as they are by what one does not or should not do. Boys, for example, perform masculinity both by choosing blue or masculine action figures, as well as by avoiding pink and dolls. Germane to the present work, existing research suggests that the exertion of authority, and by extension patterns of influence, is one way that masculinity is manifested in teams both in interactions between individuals and in the social construction of settings (Karpowitz & Mendelberg, 2014).

I concluded the previous section by describing race as ideology to argue that race, and by extension, racism, are not simply matters of individual identity. There can be racism, for example, even in the absence of students of color if the values, beliefs, and practices of the discipline delegitimize the knowledge and ways of knowing of students of color. Similarly, Kroska (2000) argues that while gender ideology is often conflated with identity (i.e., how one identifies themselves), gender ideology refers to systems of beliefs—"situational norms and routines that constrain and shape conduct in ways that produce behaviors that matches norms (and expectations) about gender" (p. 385). Here, I contend that the conceptualization of race as ideology, and the resulting operational definition of racism, allows for analysis of gender given the overlap between critical race and critical feminist descriptions of the role of Eurocentrism in marginalizing students of color and women in engineering.

In this work, the values, beliefs, and resulting practices that underlie racism and sexism in engineering are the Eurocentric epistemologies (i.e., scientific objectivity, value-neutrality, and depoliticization) that govern behaviors, and elevate or marginalize knowledge claims in engineering. Both critical race scholars and critical feminist scholars articulate mechanisms by which Eurocentric values delegitimize the work of people of color and women, namely, by adhering, at times superficially, to scientific objectivity and value-neutrality. Thus, in the next section, I discuss Critical Race Theory and how it informs my methodology in this research.

Insights from Critical Race Theory

One of the goals of this research is to understand how the dominant epistemic culture of engineering might work to marginalize students of color and women in engineering design settings. Critical Race Theory (CRT) is useful in that it "advances a strategy to foreground and account for the role of race and racism in education" (Solórzano & Yosso, 2002, p. 25), and positions researchers to examine how racism appears even in those values and practices (e.g., engineering design) that have been stripped of their explicit, formal, and codified manifestations of racial powers (Duncan, 2002).

CRT begins from the position that race and racism are normal fixtures of American society (Ladson-Billings, 1998). Critical race theorists argue the insidious ways that race and racism appear in American society often render the effects of racism invisible or otherwise difficult to recognize, confront, and eradicate (Patton & Bondi, 2015). Thus, according to Ladson-Billings (1998), one of the broader goals of the CRT perspective is exposing racism and oppressive structures in American society. As such, in this research I examine the ways in which the dominant epistemic culture of engineering might marginalize students of color in engineering education and engineering design processes. Following this framing premise of CRT, I begin with the following assumption: Racism is a normal fixture of engineering education and engineering practice (i.e., design), and it is necessary for the theoretical and empirical engineering education literature to expose the insidious ways that racism operates in engineering education broadly, and in educational processes that seek to teach engineering design specifically.

Challenge to Dominant Ideology *and* ***Critique of Liberalism***

A second tenet of CRT is the challenging dominant ideologies in U.S. society (Solorzano, 1998). Among other factors, Solorzano (1998) explicitly calls out adherence to objectivity and race- and gender-neutrality as values that "camouflage...the self-interest, power, and privilege of dominant groups in U.S. society" (p. 122). This tenet posits that one way that the normative supremacy of Whiteness is wielded is through the privileging of Eurocentric epistemologies, wherein status is granted to individuals, ideas, and perspectives that adhere to Eurocentric epistemological views (e.g., objectivity, neutrality) (Lopez, 2003). Conversely, individuals, ideas, and perspectives that diverge from Eurocentric perspective are marginalized (Lopez, 2003). Ladson-Billings (2000) notes that epistemologies are not "ways of knowing", but "systems of knowing that have both an internal logic and external validity" (p. 257). Earlier in this review, and consistent with the arguments of Cech et al. (2017), Grincheva (2013), and

Ladson-Billings (2000), I described the Eurocentric system of thinking, in terms of objectivity, value-neutrality, and depoliticization in engineering. CRT scholars have used other terms to describe the processes that conceal the normative supremacy of Whiteness and marginalize people of color. For example, Lopez (2003) notes that Eurocentric thinking conceals the normative supremacy of whiteness by adhering, at times superficially, to the ideals of *abstract liberalism*. Abstract liberalism, Lopez (2003) asserts, centers neutrality, democracy, objectivity, and equality in order to conceal racial dominance.

There is considerable overlap in the terms used by CRT scholars (i.e., neutrality and objectivity as tenets of abstract liberalism) and those used by scholars studying race in engineering contexts. For example, just as Lopez (2003) argues that the belief that "racism is an individual and irrational act in an otherwise neutral world" (p. 69) is widespread in American society, rendering "colorblindness" a laudable goal, Cech (2013) similarly refers to the ubiquitous ideology of depoliticization in engineering, wherein engineering work is often wrongly characterized as objective and value-neutral. This Eurocentric *system of thinking*, wherein ideas and knowledge are assessed, assigned value, deployed, and protected only insofar as they are perceived to be objective and value-neutral, forms the foundation of the epistemic culture of engineering that may marginalize students of color (Cech, 2013).

Still, one goal of this research is to articulate and potentially identify a mechanism by which adherence to scientific objectivity, neutrality and the ideology of depoliticization act to marginalize students of color in engineering. For example, critical race scholars acknowledge the legitimacy of experiential knowledge (Solorzano & Yosso, 2002). Similarly, technology philosopher Norström (2013) noted that "non-scientific models," such as experiential knowledge, folk theories, and obsolete scientific knowledge, are often useful sources of knowledge in engineering work, yet the empirical literature is clear that “non-scientific” knowledge, particularly knowledge originating from people of color who might bring alternative epistemologies to engineering education contexts, is often maligned or altogether excluded as valid forms of knowledge in engineering (Cech et al., 2017; Baillie et al., 2008). Indeed, Baillie and colleagues (2008) argue that “the explicit exclusion of the work and conditions of entire groups of people from the definition of engineering...makes the epistemology of engineering a subject of social justice-related concern” (p. 64). This process of marginalization or exclusion, which I call *epistemological racism in engineering*, is the focal phenomenon in this research. I begin my work with the following assumption:

> **Assumption:** Eurocentric values related to liberalism (i.e., objectivity, neutrality, depoliticization) underlie master narratives about engineering ways of thinking, knowing, and doing, and serve as mechanisms through which epistemological racism in engineering broadly, and engineering design specifically, are perpetuated.

Whiteness as Property

Critical race theory posits the status of Whiteness carries symbolic and material value that is possessed, wielded, and protected by systemic racism (DeCuir & Dixon, 2004; Lopez, 2003). According to Ladson-Billings and Tate (2016), “when students are rewarded only for conformity to perceived white norms or sanctioned for cultural practices (e.g., unauthorized conceptions of knowledge), white property is being rendered alienable” (p. 59). Thus, I argue Eurocentric epistemologies that form the crux of engineering ways of thinking, knowing, and doing are symbolic and material ways of wielding and protecting the property of Whiteness in engineering contexts by marginalizing non-Eurocentric epistemologies.

> **Assumption:** Epistemological racism is one mechanism by which the symbolic and material value of Whiteness is wielded and protected in engineering education and engineering design processes.

Colorblind Racism

Finally, critical race theorists argue that the privileging of Eurocentric epistemic frames—particularly the adherence to scientific objectivity, value neutrality, and the ideology of depoliticization—is a form of colorblind racism (Bonilla-Silva, 2015). Chapman (2013) argues that the discourse of colorblindness divorces individuals from the social, political, economic, and cultural factors that inform their racialized experiences. As a result, Whites appear reasonable when opposing epistemologies that diverge from the values of objectivity, neutrality, and depoliticization. For example, when students who base their engineering concepts (e.g., models during the solution generation process) on race-based experiences (e.g., tribal philosophies) are marginalized as a result of their failure to adhere to scientific objectivity, value neutrality, and the ideology of depoliticization, a form of colorblind racism has informed the team's approach to design. Similarly, when students believe they need to translate their ideas from race-based experiences to terms that align with Eurocentric epistemological perspectives, colorblind racism informs both the individual's and the team's approach to design.

Just as I argue that master narratives related to engineering ways of thinking, knowing, and doing are supported by Eurocentric epistemologies, I argue that adherence to these ideals is a form of colorblind racism, wherein White engineers appear reasonable while opposing the insertion of non-Eurocentric epistemologies and non-scientific knowledge in design processes.

> **Assumption:** Adherence to Eurocentric epistemological perspectives in engineering, such as scientific objectivity, value-neutrality, and the ideology of depoliticization, is a form of colorblind racism that marginalizes non-Eurocentric epistemologies in engineering education and engineering design processes.

Legal scholars Farber and Sherry (1993) challenged the state of CRT arguing that critical race theorists had not established the empirical foundation comparable to other critical theories (e.g., feminist theory). Indeed, Cabrera (2018) argues that CRT was not intended to be a theoretical framework for empirical analysis but is instead a theorizing counterspace. This means that while CRT is helpful in establishing a set of theoretical constructs and mechanisms by which race and racism might inform the engineering design process, it does not provide a set of observable, measurable factors suitable for empirical analysis. For this, I turn to concepts from Status Characteristics Theory.

How Racism and Sexism is Manifested in Working Teams: Insights from Status Characteristics Theory

A core purpose of this study is to understand how the dominant epistemic culture of engineering might result in the development of social and intellectual hierarchies in engineering design teams, wherein ideas and perspectives that align with Eurocentric epistemological values (e.g., objectivity, neutrality) are privileged, and others are marginalized. Status Characteristics Theory (SCT) suggests types of status characteristics relevant to my concern about marginalization, as well as mechanisms by which marginalization and privileging can occur: in short, SCT describes the social processes by which individual characteristics are transformed into status distinctions (Ridgeway, 2010).

This study did not entail a full application of SCT, in part, because several underlying assumptions and conditions posited in the SCT literature might not apply to engineering students' design team experiences, or were taken as assumptions in the guiding theoretical framework. For example, Ridgeway (1991) articulated several structural conditions (e.g., exchange value of resources, a correlation between nominal characteristics and the probability of being resource rich) "that are sufficient to cause nominal characteristics to acquire status value" (p. 369). My analysis did not include accounting for such conditions, in part, because the guiding theoretical framework posited such conditions as underlying assumptions. Instead, I drew on sensitizing concepts—namely, status characteristics and the behavioral sequences described in SCT—because these suggest observable, measurable processes and behaviors that can be studied in team-based engineering design settings.

SCT distinguishes at least two types of status characteristics: *specific* and *diffuse* status characteristics. Specific status characteristics are those traits germane to a limited, domain specific setting, such as perceptions of one's computer programming competence in a software design setting. SCT also describes diffuse status characteristics as characteristics that are applied across broader, more general contexts and reflect societal beliefs about performance expectations (Bianchi, 2010). Race and gender are regarded as diffuse status characteristics since, for example, Whites and males are generally believed to perform better than women and people of color in some tasks (e.g., engineering tasks). For example, Kant and Kerr (2018) describe the mythical, ideal engineer (e.g., White, man) who is likely to be more valued, as well as expected to perform more favorably than others (i.e., Black, woman). In this study, race and gender are central diffuse status characteristic under investigation.

The general premise of SCT is that status beliefs related to diffuse and specific status characteristics will translate into the individual and team-level behaviors of the group (Bowman, 2013; Bianchi, 2010). The translation assumption posited by SCT fills a gap left by the CRT framing in the previous section. That is, SCT provides a specific set of behavioral sequences—action opportunities, performance outputs, performance evaluations, and influence—theorized to underlie the development and maintenance of status-based hierarchies in groups (Bowman, 2013; Simpson, Willer, & Ridgeway, 2012). In the present framework, these behavioral sequences are presumed to be observable (i.e., the qualitative ethnographic strand) and measurable (i.e., the quantitative networks strand) in engineering design processes.

Action opportunities represent the opportunities granted to, or taken by, group members to contribute to the team (Simpson, Willer, & Ridgeway, 2012). According to SCT, high status members are assumed to take, or be granted, more action opportunities. This further contributes to their status in a team. In the present framework and study, I offer the following proposition regarding action opportunities and status hierarchies:

> **Proposition 1:** Engineering students whose epistemological perspectives align with dominant narratives of engineering ways of thinking, knowing, and doing, become high-status members who might take, or be granted, more action opportunities during the design process.

Performance outputs represent the individual contributions to the team. In SCT, high status group members are assumed to produce more performance output as a result of more action opportunities (Simpson, Willer, & Ridgeway, 2012). In engineering design settings, performance outputs might be ideas during the concept generation phase or models during the embodiment (i.e., build) phase. If it is true that the dominant epistemic culture of engineering informs the organization teamwork in design settings, then students whose epistemological beliefs align with the dominant beliefs of the disciplines might take or be granted more action opportunities and, as a result, produce more performance outputs.

> **Proposition 2:** Engineering students who adhere to scientific objectivity, value-neutrality, and the ideology of depoliticization in engineering will earn higher status on their respective design teams, which will result in more action opportunities and performance outputs.

Performance evaluations represent the positive or negative evaluations of one's performance outputs by other group members. According to SCT, all other factors being equal, the performance outputs of high-status members will be evaluated more favorably than low-status members. In design settings, all things being equal, I expect the evaluation of design concepts, for example, to be more favorable for engineers who describe or defend their concept along tenets of the Eurocentric epistemologies described in previous sections. Conversely, engineering students who propose or defend ideas and concepts from the perspective of non-Eurocentric epistemologies might receive lower explicit and implicit performance evaluations.

> **Proposition 3:** Engineering students who adhere to the objectivity, value-neutrality, and the ideology of depoliticization in engineering will receive more positive performance evaluations in team settings.

Finally, *influence* refers to the ability of individuals to utilize conscious or unconscious social pressures to modify opinions, expectations, decisions, or behaviors (Simpson, Willer, & Ridgeway, 2012). SCT posits high-status individuals exert more influence in shaping organized action (e.g., what actions are appropriate, whether particular actions should proceed). In engineering design settings, *influence* might appear in decision-making, such as the concept selection processes, task delegation processes, and presentation of ideas to particular audiences.

> **Proposition 4:** Engineering students who adhere to scientific objectivity, value-neutrality and the ideology of depoliticization in engineering will wield greater influence during the team's design process.

While the proposition above relates the dominant epistemic culture of engineering to the behavioral sequences posited by SCT via specific status characteristics (i.e., epistemological beliefs), they do not account for the role of diffuse status characteristics (e.g., race/ethnicity, gender) in the design process. SCT posits that more general beliefs about competence (e.g., Whites/men are more competent in engineering) might shape the degree to which adherence to scientific objectivity, value-neutrality, and the ideology of depoliticization are related to the four behavioral sequences.

> **Proposition 5:** Diffuse status characteristics, such as race and gender, will result in varying patterns related to the degree to which adherence to the objectivity, value-neutrality, and the ideology of depoliticization result in higher status on design teams.

Racism, Sexism, Status, and Engineering Design: An Integrated Framework

Godfrey (2014) argued that, in response to calls from professional and government bodies for cultural change in engineering, educational researchers had focused primarily on behaviors and practices, rather than the values, beliefs, and assumptions that underlie those behaviors and practices in engineering. In this research, I draw on Critical Race Theory, concepts from status characteristics theory, as well as the sociology of science and engineering, to describe the dominant epistemic culture of engineering, as well as to examine the ways dominant epistemologies shape how individuals and teams approach the engineering design process.

Drawing on CRT and, where they overlap, critical feminist scholarship, this study begins from the position that racism is a normal fixture of American society broadly, and engineering education more specifically. Second, this research assumes that one of the ways in which racism and sexism operate in engineering is through the privileging of Eurocentric values and the ideology of depoliticization. More specifically, Eurocentric values, namely the valorization, at times superficial, of scientific objectivity and value-neutrality in knowledge production and evaluation are assumed to be covert mechanisms that marginalize students who bring non-Eurocentric epistemologies, particularly students of color and women, to engineering education settings.

If it is true that knowledge and ideas from those who adhere to Eurocentric values are elevated, while knowledge from those who do not adhere to these values is marginalized, then differences in students' epistemological beliefs should inform the ideas that are elevated, marginalized, or discarded on design teams. Thus, engineering students' engineering-related epistemological beliefs are conceptualized to be a factor that informs teamwork in engineering design teams. Additionally, this research seeks to examine whether and how these beliefs shape behaviors in engineering design teams. In order to conceptualize behaviors in design teams, I draw on Status Characteristics Theory, which combines a process by which hierarchies develop on teams, but also posits a set of observable, measurable behavioral sequences that are theorized to result from these hierarchies. In full, if it is true that adherence to Eurocentric values are characteristics by which design teams elevate the knowledge, ideas, and perspectives of some students, while marginalizing or altogether discarding the knowledge, ideas, and perspectives of other students, then I anticipate finding patterns of individual and team behaviors that reflect the elevation of Eurocentric values and marginalization of others.

Chapter 3: Methods

The purpose of this research is to examine how dominant epistemic values of engineering appear in engineering design at both the individual and team levels. As described in the previous chapters, I aim to answer the following research questions:

1. How do Eurocentric epistemologies shape the ideas that first-year engineering students consider, pursue, and discard individually and in design teams in a first-year design course?
2. How do Eurocentric epistemologies influence student interactions and status hierarchies of student design teams?
3. How do Eurocentric epistemologies shape the action opportunities, performance outputs, performance evaluations, and influence on student design teams?
4. How do Eurocentric epistemologies manifest in first-year engineering design teams in ways that might marginalize the work and contributions of students of color and women?

In this chapter I provide an overview of the methodology I used to answer these questions. Specifically, I describe a convergent parallel mixed-methods design, combining a critical ethnographic approach with social network analysis to understand the role of the dominant epistemic culture in engineering in shaping individual and team-based engineering design processes. The *convergent* nature is particularly related to data analysis procedures. According to Creswell and Clark (2017), in convergent designs, researchers collect both qualitative and quantitative data simultaneously. These two sources of data are first analyzed separately, followed by a merging process wherein data from the two strands are either compared or transformed for further analysis (Cresswell & Clark, 2017). Thus, following a discussion of my positionality and how my positionality informed this dissertation research, this chapter proceeds in four parts. First, I discuss the research setting--a first-year engineering design course. Second, I discuss the purpose of the critical ethnographic approach and the details of the qualitative data collection procedures. Third, I discuss the data collection procedures in the quantitative networks strand of this dissertation research. I conclude with a discussion of the integration procedure, and how I suggest the qualitative and quantitative strands converge to expand my understanding of team-based engineering design processes.

Positionality

Madison (2012) asserts that critical ethnography "begins with an ethical responsibility to address processes of unfairness or injustice" (p. 5). My understanding of the mechanisms by which racial and gendered unfairness and injustice operates in engineering are born of my own experiences in engineering. As a Black male undergraduate engineering student, particularly as a result of my own first-year design experience, I developed a keen awareness of the ways in which race and racism informed my experiences in engineering. My racialized experiences took many forms, from explicitly racist comments and behaviors to more insidious experiences that I later came to evaluate as racist upon reflection. My research interests, and the aims of this study, are strongly influenced by these experiences and a desire to disrupt such experiences for future engineering students.

I begin by noting that in the very moment I sat down to write this positionality statement, nationwide protests in the wake of murders of George Floyd, Ahmaud Arbery, Breonna Taylor, and countless other Black American citizens, often at the hands of state-sponsored actors, have swept the country and the globe. More still, on the morning I woke to revise this section, I read that Jacob Blake is now paralyzed from the waist down after having been shot in his back in front of the gaze of his children. While I have referred to epistemic racism as insidious and covert, it is not my intent to obscure the very real, very explicit ways that race and racism, sex and sexism, and violence at the intersection of racism and sexism have and still impact marginalized people in our country. I admit the very premise of this dissertation research felt at times trivial, as I, a Black man in America, contemplated the place this research has in the context of state-sponsored killings of Black Americans around the country.

In the more specific context of engineering, my past experiences as a Black male undergraduate engineering student heavily informed the methodology and methods employed in this study, as well as ethical considerations that I insisted on honoring in this research. Indeed, one of the data collection strategies (i.e., sections of the Observation Protocol described later) is based on a dilemma I experienced in a team-based engineering design context in which my ideas were overruled by my White peers, only to be taken up later after feedback that I had "failed to contribute ideas to the team" (paraphrased quote from an engineering teammate). These experiences set me on a years-long quest to understand how and why ideas are elevated or marginalized, contributions acknowledged or maligned, and patterns of behavior deemed acceptable or unacceptable in engineering. This path led me to this dissertation study.

Moreover, my experiences as a Black male engineering student brought several ethical considerations to the fore, including my understanding of the process of *racialization*—the process through which our lived experiences become understood through our own or others' racialized lenses (Gonzalez-Sobrino & Gross, 2019). I am aware, due to my own experiences, that while the goal of this research is to evaluate events, particularly in the qualitative strand, through a CRT lens, students in ENGR 100 may not be interpreting their experiences through the same lens. Indeed, as I reflected on my own engineering experience, I realized that it was not until years later that I began to understand how race had informed my undergraduate engineering experience. I am also aware of the deep and lasting pain that *racializing* experiences not previously understood to be raced may cause students participating in this research. I thus came to a methodological dilemma: How do I honor political purpose of this research and the "ethical responsibility to address processes of unfairness and injustice" (Madison, 2012, p. 5) without causing harm to participants who may not yet understand, or altogether reject, how I posit racism and sexism are informing their lived experiences in engineering?

To address concerns about my positionality and the potential to cause harm in this research, I participated in a process of reflexive engagement. Rodriguez (2010) argued that reflexivity is a practice "in which researchers are especially concerned with issues of power, active listening, narrative and discourse, and interviewing ethics" (p. 492). I engaged in what Alexander (2003) and Denzin (1997) called subjectivist and intertextual reflexivity during both the data collection and analysis processes particularly as I began to construct the narrative of individual participants and teams in this study.

Alexander (2003) describes subjectivist reflexivity as an engagement in self-critique. I begin by acknowledging my own experiences as a Black male engineering student, as well as relating my value-laden understandings of what I observed during the qualitative strand to my own prior experiences. In practice this entailed considering, and even documenting, my preconceptions, assumptions (i.e., about individuals, teams, interactions, the setting), as well as documenting evidence that falsified my presumptions. Another way that I engaged in subjectivist reflexivity was through reflective journals, in which I documented preliminary interpretations of my observations and returned to these preliminary interpretations to either substantiate or falsify them in light of additional evidence over the course of the study. In falsifying my presumptions, I engaged in self-critique by writing about how my presuppositions or biases might have informed my early interpretations. I return to these as I discuss the findings in the following chapters.

Intertextual reflexivity refers to the situating of this research in a broader literature (Alexander, 2003; Denzin, 1999), particularly critical race and feminist literature, as well as literature on the experiences of students of color and women in engineering education and engineering settings. Critical race and critical feminist scholarship, which guided the methodology of this dissertation research, posits a set of mechanisms by which processes of marginalization are linked to raced, gendered, and race-gendered ideologies and epistemologies. Relating my observations to these literatures, noting where my judgments align or diverge for example, is one way to address threats to validity and reliability related to concerns about my positionality. I also engaged in intertextual reflexivity by discussing my research, including my interpretations of the data, with other scholars studying racialized and gendered processes in engineering teams, some of whom are cited throughout this document.

My positionality is also intimately related to what Milner (2007) calls dangers seen, unseen, and unforeseen that might arise for researchers, particularly those engaged in studies of race and culture, when they do not address their own and others' "racialized and cultural systems of coming to know, knowing, and experiencing the world" (p. 388). By *dangers seen*, Milner refers to those "dangers that can explicitly emerge as a result of the decisions researchers make in their studies" (p. 388), such as the avoidance of explicit mentions of racialized or gendered issues to participants during the study. While Milner (2007) critiqued this practice as an being founded in an epistemology of color- and culture-blindness (p. 392), this was a purposeful decision I made in order to limit the intrusion of my own epistemological perspectives in the organic behaviors and activities of the students participating in this research. To address this seen danger, I returned to issues of race and gender during one-on-one interviews only following the team-based design project.

By dangers unseen, Milner means those dangers that are “hidden, covert, implicit, or invisible in the research process” (p. 388). One such unseen danger in this study was my position as a Black male researcher studying mechanisms of racism and sexism in engineering. I recognized that my position as a racial or gender insider or outsider with respect to each participant might lead some students (i.e., those who shared my racial or gender background) to behave in ways they might not have if they understood the purpose of the study to be an examination of racism or sexism (e.g., sharing stories they ordinarily would not have shared). Conversely, I also understood that some students (i.e., those who did not share my racial or gender background) might perceive my presence as a racialized or gendered threat. One way that I responded to the potential for this *unseen danger* was to develop a language for discussing the purpose of the study in terms of understanding engineering teams’ working processes. This is how I presented the study participants:

> *I am interested in understanding how engineering teams design new systems, like your ROV. I am particularly interested in group dynamics, including how you make decisions as a team about your design, how you go about building your ROV, and how you communicate your ROV to different audiences.*

Finally, by dangers unforeseen, Milner refers to unanticipated issues that arise as a result of the decisions researchers make. For example, I made conscious decisions to connect with and build rapport with students in the focal teams. However, I did not foresee the sense students would make of their relationships and conversations with me, as well as the ways in which students perceived me to be in various communities with them. In one instance, I connected with one student in a focal team based on our shared interest in weightlifting, a topic we discussed regularly after meetings. I call this an unforeseen danger because, as I described early, while I was purposefully attending to issues of my own racialized and gendered position as a researcher in the focal teams, I had not tended to how students made sense of issues of community, particularly outside of race and gender, from their own perspective. I became aware that some students might come to see me as a friend due to shared interests rather than as a researcher examining their interactions, leading them to share things about themselves and their lives that they might not have shared otherwise. As a result of noticing and reflecting on this unforeseen danger, I developed a habit of reminding students of my intentions of reporting conversations and interactions, albeit using pseudonyms, in my dissertation writing.

Throughout this document, and particularly as I discuss my interpretation of the findings in the following chapters, I return to the dangers seen, unseen, and unforeseen I encountered in this study as I discuss methodological dilemmas and decisions, interpretations of data, and the presentation of findings.

Research Setting

Engineering design is a growing part of undergraduate engineering curricula (Prados, Peterson, & Lattuca, 2005). According to Dym, Agogino, Eris, Frey, and Leifer (2005), curricular engineering design courses occur in at least two forms: first-year *cornerstone* courses at the beginning of the engineering curriculum and culminating *capstone* courses. The setting for both the pilot and study phases of this research was a first-year cornerstone design course—Engineering 100 (ENGR 100) the University of Michigan (UM).

ENGR 100 is described as a team-based Design-Build-Test-Communicate course offered to first-year engineering students. UM offers several first-year engineering design courses, each entailing different design projects. According to the course syllabus, the course is designed to reflect aspects of a real-world mission during which students are expected to develop both technical engineering skills (e.g., design and building skills), as well as technical communications skills (e.g., report writing, oral communications skills). Students work through design proposals, fabrication, and presentations over the course of the term.

The setting for this study was a section of the ENGR 100 that utilized an underwater vehicle design project wherein students in teams of four or five designed, built, tested, and communicated remotely operated vehicles (ROV). I chose the ROV section of ENGR 100 as the setting for this research for multiple reasons. First, UM offered the ROV section of the course during both the fall and winter terms, which allowed for both fall (i.e., pilot phase) and winter (i.e., study phase) term iterations of the study. Second was an issue of access: during the pilot and study phases, I partnered with the course instructors and UM's Office of Academic Innovation (OAI) to develop the instruments and tools for data collection. For example, I collected the quantitative data described in later sections using an OAI-developed online team support tool, Tandem, the purpose of which is to facilitate research, team- and project-management, and course instruction. I describe Tandem in more detail in later sections.

Description of the Course

In the study phase of this research, the ROV project section of ENGR 100 consisted of 59 students in 11 teams of five and one team of four. At the beginning of the term, students were assigned to preliminary teams for general course orientation activities, including sessions during which students discussed the project's "Statement of Work," reviewed major deliverables (i.e., reports and presentations), and participated in skill-building activities germane to the course and project. The course instructors assigned students to their project teams following these initial orientation activities.

The course consists of three components. First, students were expected to participate in a lecture component that occurred twice per week (i.e., on Mondays and Wednesdays), during which all 59 students were present. Attendance during lecture sessions was mandatory since (a) critical information was delivered during these sessions and (b) the lecture sessions were often used as open work times during which teams discussed ideas and made progress on the project.

Second, students were expected to participate in a 50-minute discussion section focused on technical communication once each week. Due to the size of the class, students were divided into three Technical Communications sections consisting of 4 teams that met at different times each week, including a Wednesday afternoon section, a Thursday morning section, and a Thursday afternoon section. This division allowed me to choose one team per section as a “focal team” in the study.

During the technical communications sessions, students were introduced to various forms of communication in engineering, and students were often granted the technical communications hour as time to work on formal reports and oral presentations under the supervision of the technical communications instructor. Though the technical communications instructor often organized and led activities during the section, at times, instructors allowed students to use the technical communications session as open work time to make general progress on various components of the project of their choosing.

Finally, each team participated in one two-hour lab session immediately following their technical communications session. The purpose of the lab session evolved over the course of the term. For example, at the beginning of the term, before instructors placed students in their final project teams, the laboratory instructors used the time to introduce students to laboratory equipment, discuss concepts and ideas germane to the ROV project, and work with students to develop individual design ideas. Later, the laboratory session became the primary time during which students built their ROVs.

Instructional Team

The course was delivered by a team of instructors consisting of one technical instructor (Amy), one technical communications instructor (Heather), and one laboratory instructor (Mark) (all names are pseudonyms). The instructional team was assisted by three laboratory instructional assistants (IAs) (i.e., one per laboratory session), who were undergraduate students tasked with facilitating teamwork during laboratory sessions. A fourth "swing IA" also helped in the course by presenting workshops germane to the project (e.g., coding workshops). The IAs graded assignments, provided feedback to individuals and teams, and reported team dynamics issues (i.e., conflict, working relationships, progress) to the instructors in the course. Finally, the course included 12 peer mentors who were each assigned to one student team). Peer mentors had prior experience in the ENGR 100 course. Peer mentors met with their teams at least once per week (i.e., likely during the two-hour lab session), and offered guidance and feedback over the course of the project. Since the specific role peer mentors played in their respective teams differed over the course of the project, details of their involvement are reserved for later chapters.

Course Content

ENGR 100 is designed around a team-based design competition that consists of four major individual and team design assignments. In the first assignment, the *individual design proposal*, students are asked to submit an individual ROV design proposal, complete with sketches and a rationale for their design decisions. Students submitted their individual design proposals prior to entering their final project teams, in part, to facilitate initial team discussions. This detail is important since one of the goals of this research was to understand how students negotiated ideas. The fact that students had individual preliminary design proposals meant that the case in which a student's ideas were absent in team discussions was likely not due to that student having not had ideas prior to the team's initial meetings. The individual design proposal ensured all students had done some preliminary thinking before they entered their final teams. During one-on-one interviews, I returned to the individual design proposal to understand how students developed, communicated, and defended their ideas in their respective teams.

Assignments two through four consisted of three team presentations to the course instructional team. These presentations, called the *preliminary design review* (PDR), *detailed design review* (DDR), and *critical design review* (CDR)[2] are intended to facilitate team decision-making, offer opportunities for feedback from instructional staff, and help teams clarify outstanding questions. For example, during the preliminary design review, teams were asked to present up to three designs under consideration, as well as any debates or outstanding questions they might have. The process for preparing the PDR entails the negotiation of ideas across the individuals in the team and, ultimately, the selection of two to three ideas for the presentation. The instructional team explicitly told students that some teams might choose to simply present three of the five individual design proposals during their PDR. Other options include "mixing-and-matching" ideas from across the five individual design proposals, workshopping (i.e., team-based modifying) particular individual design proposals, or generating two to three wholly new designs for the PDR.

[2] Due to the onset of the COVID-19 pandemic and resulting transition to online learning, students did not present a Critical Design Review. Instead, students wrote a Design Report outlining and describing final decisions in their design processes.

During the Detailed Design Review (DDR), teams were asked to present their ideas to both the instructional team as well as other students in the class. For the DDR, teams were to have narrowed down their major design components. While open questions were still acceptable and encouraged during the DDR, teams were to have made enough decisions to present preliminary budgets and key calculations, such as the estimated speed and coefficient of drag of their team's ROV. Unlike the PDR, which is a closed meeting that included only one or more instructors and, at times, course alumni who provide feedback and suggestions, the DDR included an open question and answer session from other teams in the course. The DDR, then, became a key venue for understanding how students presented and defending their ideas to larger engineering audiences.

Finally, during the Critical Design Review (CDR), the final team presentation during the design process, teams were to present a near finalized design (i.e., the ROV they intend to build). However, due to the onset of the COVID-19 pandemic and the institution's decision to move all instruction online, the CDR did not occur during the study phase. Instead, students submitted a written design report that included their final design, important calculations and budgets, as well as rationales for their design decisions, and a scaled version of their ROV design. These major presentations and reports are important milestones in the course, particularly given the theoretical frameworks guiding this study, since they entail different sets of action opportunities and, as a result, varying types of performance outputs, evaluations, and influence on the teams.

Team Formation

At the start of the term, students were placed in preliminary teams of five for the introductory orientation lectures. The instructional team formed the final project teams following four weeks of introductory material (e.g., a project overview, project-related technical engineering education). The instructors determined teams with a number of project management considerations, as well as learning goals related to teamwork and communication in mind. For example, instructors discussed the role of demographic characteristics in forming teams, noting a desire to (a) avoid isolating racially/ethnically minority students and (b) avoid "stranding women" (i.e., placing a woman on a team with only male peers).

Other considerations during the team formation process included students' living arrangements. Instructors attempted to place students with teammates who lived in the same residence hall or in nearby residence halls. The instructional team made this decision because students live across two main campuses in Ann Arbor, North and Central campuses, which require a campus bus or other transportation. Knowing that students might work late hour, which would require them to travel to their respective residence hall after dark when some students might not feel safe, instructors tried to match students' campus living arrangements,

Finally, instructors considered known prior conflicts in the team formation process. Students were told that the instructional team was in the process of finalizing teams. Each student was offered an opportunity to send the instructors a private message with any student they did not want to work with over the course of the project. Students were informed that this was a "no-questions-asked" policy—if Student A asked not to work with Student B for any reason, or for no reason at all, the instructors ensured Student A and Student B would not be placed on the same team. Given my place as a researcher in the setting, the instructional staff informed me of the three messages they received to this effect. However, to preserve anonymity, I do not report the details of those requests.

While the instructors gave me the opportunity to influence team formation, I deferred to course instructors for several reasons. First, I felt strongly that the priorities of the instructors (e.g., avoiding "stranding" women) should remain intact, as they reflect both instructors' experiences garnered from years of teaching design courses, as well as their beliefs about appropriate conditions for maximizing students' learning in ENGR 100. While it served as a research setting for me, ENGR 100 is first, and foremost, a learning environment that might inform students' pathways through engineering education. Thus, ethically, my priority was to ensure that my study did not impede students' learning experiences in ENGR 100.

Additionally, I wanted to avoid creating the conditions under which I expected to see the phenomena of interest (e.g., epistemological racism, sexism) for ethical reasons. Here, I draw on my own experiences and positionality; I recognize that feelings of isolation and marginalization have an inherently taxing effect on students of color and women in engineering. For this reason, I felt it would be unethical to assert power as a researcher over students' experiences by putting them in conditions that might become academically, socially, or psychologically taxing solely for the purpose of this study.

Team Selection

On the day the instructional team introduced students to their final project teams, each team was given a set of assignments for the day's class activities. Teams were to (a) choose a method for group communication (e.g., messaging applications like Slack, GroupMe, or WhatsApp), (b) establish methods for sharing documents (e.g., a shared Google Drive), and (c) discuss whether or not they would invite me to observe their teamwork over the course of the semester. I reminded the teams that I would only select their team if all members agreed to participate. I was also aware that the social situation (i.e., being on a new team) might lead some students to avoid early conflicts by agreeing to participate in the study if, for example, they were the one member of a five-member team that wished to be excluded from observations. For that reason, during these initial team discussions, the instructors and I offered students the opportunity to ask me questions about the study, the scope of my involvement in their team, incentives for participation, and any other information students might want before they made individual and collective decisions to join the study. I also offered students opportunities to reach out to me individually with any concerns, and I reminded students that informed consent was an ongoing process—they could withdraw from the study at any point, for any reason, or for no reason at all.

Of the 12 teams in the class, nine teams invited me to participate in their teams over the course of the semester. I selected three of the nine teams as focal teams for this research (i.e., one team per technical communications/laboratory section). Team selection proceeded based on three criteria. First, only those teams that explicitly invited me to participate in their teams were considered. Second, I considered the racial/ethnic and gender diversity of the teams that came forward. Finally, I considered epistemic diversity, as measured by the Engineering-related Beliefs (ERB) survey students completed at the start of the term and described in later sections. Specifically, I chose teams where the range of ERB scores were largest. For example, if two teams had similar racial/ethnic and/or gender diversity, I chose the team in which ERB scores varied more widely as a focal team. The three teams I chose—The Yachtsmen, Team Mobula, and Team Surge (all pseudonyms)—are presented in Table 1, as are pseudonyms for the student members, their racial/ethnic and gender identities, and international student status.

In the next sections, I describe the data collection procedures for both the qualitative critical ethnography and quantitative networks strand of this research. I also describe the analysis process for each strand and discuss how I merge both strands to answer the four research questions in this study.

Table 1. Demographic Characteristics of Focal Teams

	Race/Ethnicity	Sex	International Status
Team Mobula			
Matthew (Matt)	White	Male	Domestic
Chelsea	White	Female	Domestic
Max	Asian	Male	Domestic
Adaeze (Addy)	Black	Female	International
Kevin	Asian	Male	Domestic
Team Surge			
Danish	Asian	Male	Domestic
Lauren	White	Female	Domestic
Ryan	White	Male	Domestic
Rehman	Asian	Male	Domestic
Stephanie	White	Female	Domestic
The Yachtsmen			
Kyle	White	Male	Domestic
Paul	White	Male	Domestic
John	White	Male	Domestic
Seth	White	Male	Domestic
Cameron (Cam)	White	Male	Domestic

Methodology Overview

I employed a convergent parallel mixed-methods design, combining a critical ethnographic approach with social network analysis to understand the role of the dominant epistemic culture in engineering in shaping individual and team-based engineering design processes. In the qualitative critical ethnography strand, I utilized three data collection strategies—observations (documented in ethnographic fieldnotes); one-on-one, semi-structured interviews (i.e., the Design Experience Interviews); and peer mentor journals—to understand how the dominant epistemic culture of engineering shapes team-based engineering design processes. In the quantitative networks strand, I collected survey data over the course from all students in the course. The surveys including questions on students' engineering related beliefs and their self- and peer-evaluations. The relationships between the data collection strategies and each research question are presented in Table 2. Figure 1 presents a timeline of the research activities as they relate to assignments in ENGR 100.

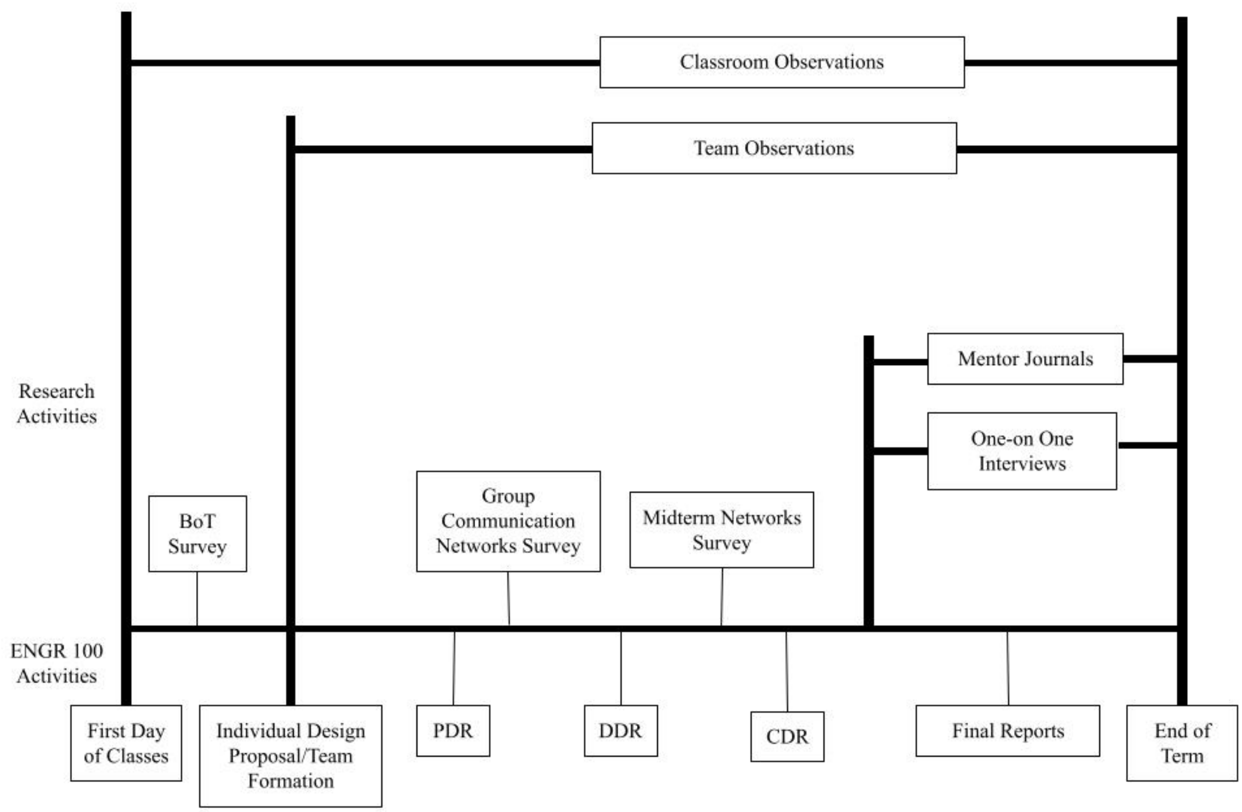


Figure 1. Timeline of research and ENGR 100 Activities

Table 2. Relationships Between Research Questions and Data Sources

Research Question	Related Data Sources	Variables and Sensitizing Concepts
Research Question 1: How do Eurocentric epistemologies shape the ideas that first-year engineering students consider, pursue, and discard individually and in design teams in a first-year design course?	**Qualitative:** • Fieldnotes • Design Experience Interviews	• Epistemological Beliefs (Individual) • SCT Behavioral Sequences
	Quantitative: • Beginning-of-Term Survey Data	• Engineering-Related Beliefs Survey
Research Question 2: How do Eurocentric epistemologies influence student interactions and status hierarchies of student design teams?	**Qualitative:** • Peer Mentor Journals/Interviews • Fieldnotes • One-on-one Interviews	• Epistemological Beliefs (Individual and Team) • SCT Behavioral Sequences
	Quantitative: • Group Communication and Midterm Networks Survey	• Idea Contributions • Idea Enactments
Research Question 3: How do Eurocentric epistemologies shape the action opportunities, performance outputs, performance evaluations, and influence on student design teams?	**Qualitative:** • Fieldnotes • Peer Mentor Journals/Interviews • Design Experience Interviews	• Epistemological Beliefs • SCT Behavioral Sequences
	Quantitative • Group Communication and Midterm Networks Survey	• Idea Contributions • Idea Enactments
Research Question 4: How do Eurocentric epistemologies manifest in first-year engineering design teams in ways that might marginalize the work and contributions of students of color and women?	**Qualitative:** • Peer Mentor Journals/Interviews • Design Experience Interviews • Fieldnotes	• Race/Ethnicity • Gender • SCT Behavioral Sequences
	Quantitative • Group Communication and Midterm Networks Survey	• Idea Contributions • Idea Enactments • Race/Ethnicity (as variable) • Gender (as variable)

Critical Ethnography Strand

Stanley and Wise (1990) distinguish method—"techniques or specific sets of research practices, such as surveys, interviews, or ethnography"—from methodology[3]—"a perspective or very broad theoretically informed framework...which may or may not have its own particular appropriate research method/s or technique/s" (p. 26). The methodology utilized in this study was guided, in part, by Critical Race Theory (CRT). CRT informs a number of methodologies in educational research. For example, CRT elevates lived experiences and storytelling as legitimate forms of presenting and interpreting evidence (Parker & Lynn, 2002). Thus, narrative inquiry and counter-storytelling are often-used methods in qualitative research framed in CRT. Since this research sought not only to understand how students experience the value-laden structures of engineering, but the degree to which students reify those structures in the daily practice of engineering (i.e., engineering design), I employed a critical ethnographic approach.

Ethnographic Data Collection Strategies

I used several strategies for collecting qualitative data that were informed by the theoretical framework guiding this research, practical considerations related to the design of the ENGR 100 course, and dangers seen, unseen, and unforeseen in this study. First, I documented my observations of discussions and interactions in the three focal design teams through fieldnotes and a reflective journal. Second, I conducted semi-structured interviews with ENGR 100 students in the three focal teams at the end of the term to ascertain their understandings and perspectives about their experiences over the course of the project. Finally, to supplement quantitative data on the teams that I did not observe, I collected information about the design

3 While Stanley and Wise (1990) list ethnography as "method", Lillis (2008) notes that the term ethnography is often used to describe a method alongside other methods such as interviews and observations, or as a methodology "constituted by multiple methods" (p. 355).

process from the peer mentors working with each team in the course. The purpose of each of these data sources, as well as their relationship to the overarching research questions, are discussed in the following sections.

According to Emerson, Fretz, and Shaw (1995) ethnographic research entails two activities: (a) entering and participating in a social setting in order to develop relationships with participants and observe their everyday lives and (b) writing down what one observes in regular, systematic ways in order to create a written account of observations and experiences. Thus, in this section I describe the process by which I gained access to, and built rapport with, particular teams, as well as the systematic approach I took to document what I observed and experienced in ENGR 100 in ethnographic fieldnotes.

Positioning Myself in the Classroom

A key element of any ethnographic study is gaining access to participants for observations (Harrington, 2003). Harrington distinguishes access from entry and rapport in ethnographic research. That is, whereas entry refers to a singular act, and rapport refers to the quality of relationships between the researcher and participants, access is an ongoing process through which entails tending to a number of aspects including: (a) facilitating the researcher-participant relationship for information gathering during the study, (b) tending to issues of identity and power for both myself and participants throughout the study, and (c) understanding the practical implications of the methods of information gathering for both the researcher and participants (Harington, 2003). In this work, I attempted to tend to all three—entry, rapport, and access—as matters with ethical implications, as well as issues of methodological rigor.

Introducing Myself and Gaining Entry

At the start of the term, I worked with the ENGR 100 instructors to develop a strategy for positioning myself as a researcher in the classroom. This entailed both discussions about appropriate behaviors during the class period, as well as the process by which I identified the three teams that I observed most closely, henceforth referred to as *focal teams*, during the study. During these discussions, I, along with the course instructors, developed processes for both the formal process of establishing the researcher-participant relationship (e.g., Institutional Review Board-approved procedures such as informed consent), as well as the informal process of positioning myself as an actor in the ENGR 100 classroom broadly, and in the three focal teams specifically. Here, I discuss positioning myself in the classroom specifically as it relates to methodological decisions that informed (a) how I was represented to students in the classroom and the participants in this research and (b) how I carried out particular aspects of the study.

On the first day of classes, the course instructors introduced me to the class as a doctoral student in education interested in studying how engineering teams complete their work. I was invited to introduce myself to students after the instructors introduced themselves to the class. I was careful to present particular information about myself, in part, to establish myself as a legitimate participant in the course. For example, the technical communications instructor, Heather, had repeatedly told me that she was often concerned that students did not engage her in particularly technical conversations because, as a communications instructor, they might have perceived her as lacking engineering legitimacy with respect to technical knowledge. As a result, I was purposeful in telling students about my background in computer science and engineering, as well as my experiences in engineering design teams, such as the teams they were preparing to engage in.

As I assumed that asking students to agree to be "researched" might cause consternation, I also invited students to ask questions over the course of the first several weeks (i.e., prior to entering their final project teams). Several students openly joked about "how cool it would be to be the researched" and asked questions about my work. Others expressed interest in education research and offered their own perspectives on important topics in engineering education research that they wanted to pursue. For example, one student discussed the lack of women in her engineering classes, while another joked that they were learning about ethnographic research in another class after I said I was engaged in an ethnographic study. These types of conversations helped me get to know potential participants, established me as a fixture in the ENGR 100 class, and ultimately helped me build rapport with students in the focal teams.

Gaining Access and Building Rapport

The process of gaining access to the three focal teams did not occur solely following the team selection process. During the pilot study, I learned from discussions with students that my methods for recording jottings (i.e., using an electronic tablet) "took some getting used to" on their part. I noticed multiple students straining to see what I was jotting down during the class or lab sessions, and multiple students noted some degree of awkwardness related to my presence. As a result, I chose to begin the process of recording fieldnotes earlier during the study phase so that students might become accustomed to my presence and writing habits. I also offered students the opportunity to read my handwritten notes if they were curious or if reading my notes might help them become more comfortable with my presence, but no one took up the offer.[4]

Second, I both announced and reiterated to students that my role in the classroom was one of a researcher. In an effort to relinquish as much power, real or perceived, in my

[4] Note: Fieldnotes recorded prior to the team selection process were not considered in the analysis in this research. I recorded these fieldnotes solely for the purpose of rapport-building with students in the classroom.

relationships with students in the class, I made a set of announcements upon my introduction. First, I announced that I had no part in assigning students' grades whatsoever. I also promised students that I would not report my observations in the classroom or in their respective teams to the instructional teams, save for times when I am required by law or ethical reasoning (i.e., for the safety and wellbeing of participants or other students in the classroom). This did occur multiple times throughout the study. For example, during one laboratory observation, I noticed two students using a piece of machinery in a fashion I believed to be improper and unsafe. I notified one of the IAs in the laboratory of this, and suggested the IA speak with the students about proper use of the equipment.

Still, I recognized that students might have perceived me in ways that I was not aware of upon entry into the classroom and throughout the research process, and there were signs that students were at least somewhat unsure of my role throughout the term (e.g., one student referred to me as a "higher up" in the room, and I was included in one email requesting a grade change at the end of the term). As a result, and consistent with the view of access as a *process*, I continued dialogues with students about my role, reminded students that any advice I gave during the design process was not binding for the instructional team who assigned their grades, and participated in further conversations about my role throughout the project.

Importantly, my participation in the teams was framed as an *invitation from students* to join their teams. Accordingly, only teams that explicitly expressed an invitation for my participation were considered in my choice of focal teams. During the informed consent process, I reminded students that they could rescind their invitation at any time and for any reason or no reason at all. I also reminded students that it was my goal that my presence did not hamper their teamwork, and that they should feel free to tell me if that were the case (e.g., if I needed to physically move or leave the setting to help facilitate their design work).

Ethnographic Fieldnotes and Reflective Journal

Over the course of the study, I engaged the three focal teams in ongoing observations both in the classroom, as well as in their meetings outside of the scheduled class time. In order to document my observations, I developed an observation protocol to guide my thinking as I engaged and interacted with each of the focal teams (Appendix B). The observation protocol consisted of three sections. The first section, the *Course Overview*, was designed to provide me with the opportunity to describe characteristics of ENGR 100 critical to understanding students' design experiences. These characteristics include the course instructional staff, the rooms (i.e., lecture, discussion, and laboratory spaces) in which the course is delivered, and the regular days and times in which the course meets. This was undertaken to document how each room offered various affordances for facilitating teamwork (i.e., some rooms were flexible with wall-mounted monitors for each team to work from, while others were not flexible and featured no monitors). I thus found it necessary to document how the rooms might affect the team's design processes.

The second section of the observation protocol, the *Classroom Observation Form* was developed to align with the design of ENGR 100. Instructors describe the course to students as "first and foremost a communications course." As a result, there were often times when students were participating in activities that were not themselves design- or building-related activities, such as team building activities. These portions of ENGR 100 became critical to document in field notes since they were often times in which the instructional staff communicated ideas about engineering work, engineering ways of knowing, and engineering knowledge to the class. Thus, this portion of the observation protocol was designed to draw my attention to the ways in which the instructional staff communicated ideas related to the valorized components of the epistemic culture of engineering described in Chapter 2 (i.e., scientific objectivity, value-neutrality, depoliticization). This section asks questions such as, “How do instructors/students discuss objectivity in knowledge creation and evaluation?” The purpose of this classroom observation data is to understand the degree to which Eurocentric values (e.g., scientific objectivity, value-neutrality, depoliticization) are communicated to students by instructors.

The last portion of the observation protocol, the *Team Observation Form,* was designed to facilitate my observation of teams’ design-related activities. This section of the observation protocol was designed specifically to focus my attention to the four behavioral sequences posited the by Status Characteristics Theory component of my conceptual framework (i.e., action opportunities, performance outputs, performance evaluations, and influence) (Simpson, Willer, & Ridgeway, 2012). For example, under “action opportunities”, the protocol asks me to respond to the question, “In what ways do students try to appropriate or avoid particular action opportunities?” Similarly, under “influence”, the protocol asks me to respond to the question, “In what ways do students seem to control information flows on the team?”

Additionally, because this research examined the role of Eurocentric epistemologies in team-based engineering design work, the last section of the Team Observation Form drew my attention to ways that students presented, defended, pushed back on, or otherwise engaged and negotiated with ideas during the design process. This section of the protocol, titled *Epistemic Cognition,* asked questions such as, “What sources of knowledge do students draw on to describe and defend their ideas?” The full protocol is in Appendix B.

Additionally, I documented my ongoing interpretations of my observations, including my preconceptions and assumptions, syntheses of patterns within and across teams, as well as dangers seen, unseen, and unforeseen and my resulting responses to those dangers, in a reflective journal. I also documented incidents, such as major design decisions and debates, that I wanted to return to for clarification in one-on-one interviews at the end of the term with members of the three focal teams in my reflective journal. As the reflective journal is not itself data, I did not code journal entries. Rather, I returned to the journal throughout the analysis process in order to revisit, refine, clarify, or falsify prior entries in light of new evidence.

Student Interviews - The Design Experience Interview

Second, I conducted semi-structured interviews with each student in the three focal teams. The semi-structured interviews, the henceforth referred to as the *Design Experience Interview* occurred near the end of the project as students completed their final design reports for the course. I had planned to conduct these interviews in person, but the onset of the COVID-19 pandemic required I conduct each interview virtually. By the time of the interviews, I had been with the team for nearly 11 weeks, which facilitated the virtual interview process.

The purpose of the Design Experience Interview was twofold. First, I sought to understand how students experienced the various portions of the design process, beginning with drafting their individual design proposals and including how they presented their individual design proposals to their teams, developed their teams initial and final designs, and presented those designs to their peers and instructors. For example, during the first portion of the Design Experience interview, I asked students to describe their individual design proposals, including how they conceived of the idea and why they believed the design would be effective, to capture elements of epistemology.

The second portion of the Design Experience Interview elicited stories about how students experienced teamwork on their design teams, including the processes of presenting and negotiating ideas, building the ROV, and communicating the ROV to various audiences. The second portion of the interview was designed around the four behavioral sequences posited by Status Construction Theory (i.e., action opportunities, performance outputs, performance evaluations, and influence), specifically asking students to reflect on the activities they engaged in, those they avoided or were otherwise unable to engage in, and how the team's working processes might have influenced these behavioral sequences.

Additionally, prior to the individual interviews, I re-read my fieldnotes and reflective journals to develop questions asking students to reflect on particular incidents during the project (e.g., major decisions, arguments the teams had, ideas the team took up or discarded). I developed questions for the Design Experience Interviews that allowed students to reflect on those particular instances in order to describe how they made sense of them, as well as any follow-up that might have occurred out of my view. I detail these instances, as well as students' responses to those instances, in the chapters that follow.

Finally, I engaged in a process of member checking during the individual interviews. To do so, I drafted Team and Individual profiles, which I present in the Findings chapters with general overviews of my perceptions of each team, as well as each team member's role on their respective team. During the one-on-one interviews, I offered each student the opportunity to read these brief profiles of themselves and their teams to identify (a) places that they disagreed, (b) places that they wanted to clarify, and (c) ideas that they hoped I would represent in my writing about them and their teams that might not have been captured. Notes from individual students are captured in the Findings chapter, and I particularly draw attention to places that I revised my writing and understanding of individuals and team dynamics that were based on my conversations with students during their respective interviews. The interview protocol for the Design Experience interview can be found in Appendix C.

Mentor Journals

Finally, since peer mentors assigned to each team were tasked with working closely with their respective teams throughout the course of the project, the instructional staff suggested the peer mentors might be useful sources of qualitative data to complement the qualitative data, particularly for the nine non-focal teams. In particular, it was suggested that journaling might be a useful strategy for (a) identifying teams that are having issues that might not be apparent from quantitative data alone and (b) generalizing qualitative findings from the three focal teams to the course. As a result, I developed brief journal prompts to elicit particular information about each mentor's respective team.

Journal prompts (Appendix D), like other aspects of this research, tapped the four behavioral sequences posited by SCT. For example, I asked mentors to write about which students participate in particular tasks (i.e., action opportunities) and how tasks are delegated (i.e., influence). Other questions asked mentors to reflect on patterns of communication (e.g., who is communicating with the mentors, what types of questions were asked, do any students dominate the team's meeting, do students provide each other verbal feedback) to elicit information about performance evaluations and influence.

The journal prompts were piloted before the study began with three ENGR 100 peer mentors assigned to prior ENGR 100 courses. In these short (15 - 25 minute) meetings I sought to determine if the prompts would elicit the types of information needed, as well as mentors' ideas about when these journals should be collected and how they should be used in the context of the broader study. All three peer mentors interviewed during the pilot phase noted that some questions were difficult to answer early in the semester, when mentors had only met with their teams once or twice. For this reason, during the dissertation study, I collected journal responses near the end of the term following each team's submission of their design report. Initially, I planned to collect peer mentor journals at two points during the project. However, the onset of the COVID-19 pandemic led to several changes in the course, including the change to virtual assignments and teamwork. As a result, I collected peer mentor journals one time at the end of the term.

Eight of the nine peer mentors for non-focal teams in the course submitted journal entries at the end of the term, as well as one peer mentor from a focal team. As the purpose of the journals was to supplement the quantitative data, I return to the peer mentor journals as I discuss the quantitative findings in later chapters.

Social Network Analysis Strand

In the quantitative strand of this research, I studied engineering design teams as social networks of students, utilizing a social network analysis to understand how individual characteristics inform the nature and structure of team-based engineering design processes. Borgatti, Everett, and Johnson (2013) describe social network analysis (SNA) as a way of thinking about social systems that focuses our attention on the relationships among the actors (e.g., engineering students) that make up the system (e.g., design team, classrooms). As Grunspan and colleagues (2014) note, SNA "aims to understand the determinants, structure, and consequences of relationships between actors" (p. 168). Thus, it is necessary to describe the participating students, instructors, and peer mentors (called actors or nodes in social network theory) in this social system, as well as the nature of the relationships between actors in the network.

Quantitative Data Collection Strategy

In this section I describe how I operationalized the four behavioral sequences posited by Status Construction Theory (i.e., action opportunities, performance outputs, performance evaluations, influence) in terms of network analysis principles. Since the data in this quantitative strand is collected via an online team management tool, Tandem, I briefly describe Tandem's use in the course and in my data collection strategy.

Tandem is an online tool under development by the Office of Academic Innovation in partnership with ENGR instructors at the University of Michigan. Tandem is intended to help student teams manage their design projects, and offers students opportunities for self and team evaluations, the latter of which I used in the quantitative strand of this study.

I collected quantitative data using three surveys delivered via the Tandem web tool. First, I measured epistemological beliefs using the Beginning of Term Survey that students completed up entry in the class. Second, I conceptualized the set of teams as a collection of two networks: *contribution* networks, where ties among team members represent perceptions that teammates are contributing ideas (Group Communication Networks Survey) and *enactment* networks, where ties represent perceptions that a particular students' ideas were actually utilized by the team (Midterm Networks Survey). I describe each survey and its respective measures in the next sections.

Beginning of Term Survey: Measuring Epistemological Beliefs

The Beginning of Term Survey (Appendix E) collected initial data related to ENGR100 students' epistemological beliefs. Instructors also used the Beginning of Term Survey to collect information for team-building purposes. It included an original instrument designed to assess the degree to which students supported Eurocentric epistemic values in engineering. Although several scales that measure engineering-related epistemological beliefs exist, none were rigorously validated at the time of this study, and extant evidence raised questions about their validity and reliability. Second, the goal of this study was not to measure and understand epistemologies broadly, but to understand adherence to particular epistemological beliefs associated with Eurocentric views of engineering and science. This required creating and pilot testing specific survey items.

Nonetheless, some prior research was useful to me in the instrument development phase for identifying potential areas for investigation. For example, Faber and Benson (2017) utilized the Engineering-Related Beliefs Questionnaire developed by Yu and Strobel (2011) to study epistemic cognition in engineering problem solving and found several constructs had low internal consistency. Two items were taken from Yu and Strobel (2011), as listed in Faber and Benson (2017), because they both reflected the core constructs germane to this study (i.e., scientific objectivity, value-neutrality, and depoliticization). For example, the item "In engineering, first-hand experience is as valid a source of knowledge as knowledge established by experts" in the process objectivity scale described in Table 3 was an adaptation of Yu and Strobel's item, "First-hand experience is the best way of knowing something in engineering." Additionally, the item, "Technical engineering problems have only one right answer" in the product objectivity scale was an adaptation of Yu and Strobel's, "Engineering problems have only one right answer."

The additional measures used to measure epistemological beliefs (see Appendix E) align with a set of definitions and concepts provided by (a) Critical Race Theory, (b) philosophy of science and technology literature, and (c) sociology of science and technology literature (as described in my discussion of the literature). In particular, these measures were developed around CRT's *critique of liberalism* tenet and related definitions of objectivity and neutrality, as well as the concept of depoliticization in engineering education provided by Cech and Sherick (2015). I also drew on definitions of *scientific objectivity* provided by philosophy of science and technology literature to develop items to measure the degree to which students adhere to tenets of abstract liberalism. For example, I drew on the Stanford Encyclopedia of Philosophy (Reiss & Springer, 2017), which describes scientific objectivity as a value that can be understood in two ways—product and process objectivity—to develop items measuring adherence to objectivity in engineering.

Depoliticization refers to the belief that engineering is solely a technical field devoid of cultural and social concerns (Cech & Sherick, 2015). The ideology of depoliticization, according to Cech and Sherick, fosters an approach to engineering that assumes political and social issues can and should be separated from engineering work and become embedded in engineering students' epistemologies due to professional socialization processes in engineering education. Items measuring the degree to which students adhere to the ideology of depoliticization in engineering reflect Cech and Sherick's (2015) definition. Table 3 defines the constructs of scientific objectivity, value-neutrality, and depoliticization and lists resulting items.

The scales were piloted through three processes. First, experts in survey design at the university's Center for Education, Design, Evaluation, and Research reviewed the set of original survey items to establish face validity. Second, I conducted a focus group with one five-member team enrolled in ENGR 100 during the pilot study using a protocol to elicit (a) whether or not students understood the meaning of the items on the survey as I intended, and (b) whether or not the students were confused by the items in the survey, and (c) how students interpreted different versions of the same item (e.g., "Engineers should leave their *personal beliefs* out of their engineering work" and "Engineers should leave their *cultural beliefs* out of their engineering work"). Additionally, I established construct validity using a sample of 163 engineering students, including a set of first- and second-year engineering students not enrolled in ENGR 100, as well as the students enrolled in ENGR 100 during the pilot phase.

Table 3. Operating Definitions of Objectivity, Neutrality, and Depoliticization and Resulting Items

Description of the Epistemic Culture of Engineering	Items Measuring Students' Adherence to the Epistemic Culture
Objectivity: Refers to the employment of specific ways of observation and experimentation (Grincheva, 2013). Recognizing science and scientific inquiry as the most trustworthy source of knowledge (Grincheva, 2013). *Scientific objectivity* expresses the idea that the claims, methods, and results of science are not, or should not, be influenced by particular perspectives, value commitments, community bias, or personal interests (Reiss & Springer, 2017). Product Objectivity: Science is objective in its products - theories, laws, experimental results, and observations. Process Objectivity: Science is objective in that, or to the extent that, the processes and methods that characterize it neither depend on contingent social and ethical values, nor on the individual bias of scientists.	**[Process Objectivity]:** 1. Engineers should rely on math and science when defending their ideas. 2. In engineering, first-hand experience is as valid a source of knowledge as knowledge established by experts. 3. Math and science are the best ways to defend ideas in engineering 4. If engineers follow mathematical and scientific principles, they will always find the best solutions. 5. Engineers should rely on math and science when **communicating** their ideas. **[Product Objectivity]:** 1. Knowledge in engineering can always be proven true or false. 2. Knowledge in engineering is objective. 3. Knowledge based in math and science is the most valid form of knowledge in engineering. 4. Principles in engineering cannot be argued or changed. 5. Interpretations of engineering knowledge should not change from person to person. 6. Technical engineering problems have only one right answer.
Neutrality/Depoliticization: Neutrality is one conception of objectivity as defined by Reiss and Springer (2017). The belief that engineering work, by definition, should disconnect itself from social and cultural realms because such realms taint otherwise pure engineering design methodologies (Cech, 2013). Sanctions the separation of social justice concerns from engineering work (Carter et al., 2019).	1. Engineers should leave their personal beliefs out of their engineering work. 2. Social justice concerns should not influence engineering work. 3. Political beliefs should not influence engineering work. 4. Cultural beliefs should play no role in the creation of engineering knowledge. 5. Engineers should leave their cultural beliefs out of their engineering work. 6. Human emotions should play no role in engineering work. 7. Engineers should leave their personal opinions out of their engineering work. 8. Engineering knowledge is value-free. 9. Political beliefs should not influence solutions to real-world engineering problems.

Since the research questions guiding this study required that I develop methods for assessing students' individual epistemologies before I could try to understand the role of individual epistemologies in team-based design processes, and since I drew on these beliefs for team selection at the start of the term, I began by assessing students' responses to the Engineering-Related Beliefs (ERB). This required I first evaluate the efficacy of using the ERB scales for assessing students' beliefs about scientific objectivity and depoliticization in engineering work. I established construct validity using structural equation modeling. Specifically, I used confirmatory factor analysis (CFA) to examine the items in the ERB scales across the three latent constructs (i.e., process objectivity, product objectivity, and depoliticization) as described in the previous chapters. Since variables measuring engineering-related beliefs were continuous, I used the maximum likelihood with robust standard error (MLR) estimator to fit the initial measurement model. The measurement model was first established by assessing the loadings of observed variables onto their specified latent constructs.

SEM fit indices recommended for models with continuous variables include the root-mean-square error of approximation (RMSEA), the comparative fit index (CFI), the Tucker-Lewis index, and the standardized root mean square residual (SRMR) (Kline, 2005). I compared model fit indices to criteria established by Hu and Bentler (1999). For example, Hu and Bentler recommend absolute fit indices, such as the RMSEA and SRMR, not exceed .06 and .08 respectively. Moreover, Hu and Bentler suggest incremental fit indices, such as the Tucker-Lewis Index (TLI) and the Comparative Fit Index (CFI), exceed .95.

Initial model fit indices offered little support for acceptable model fit according to criteria established by Hu and Bentler (1999) (CFI = .900, TLI = .884, RMSEA = .057, SRMR = .066). I then examined factor loadings and modification indices in order to assess whether modifications to the model (e.g., removing items, moving items to different latent constructs) might improve model fit. As a result, I removed four items from the ERB scales. First, I removed the item, "In engineering, first-hand experience is as valid a source of knowledge as knowledge established by experts" (standardized factor loading = .217), since the low factor loadings, indicated a weak relationship with the process objectivity construct.

Similarly, I removed two items (i.e., "Political beliefs should not influence engineering work." and "Human emotions should play no role in engineering work.") from the depoliticization subscale since their relatively low factor loadings, indicated the two items were not suitable for measuring students' adherence to Eurocentric epistemologies in engineering. Following these modifications, I examined new model fit indices against the criteria described by Hu and Bentler. New model fit indices (CFI = .968, TLI = .961, RMSEA = .035, SRMR = .056) indicated the revised scale was a good fit to the data. Table 4 below compares the original and revised models for the full ERB scales.

Table 4. Comparison of Model Fit Indices

Fit Index	Measurement Model	Alternative (Revised) Model
RMSEA	.057	.035
SRMR	.066	.056
Tucker-Lewis Index	.900	.968
Comparative Fit Index	.884	.961

Like other measures of personal epistemologies, some of the measures included in this study exhibited low internal consistency, and the low factor loadings (see Table 6 below) might reflect a limitation of the scales. For example, there is a lack of consensus in what constitutes an appropriate cutoff for factor loadings that call into question the instrument used in this research. While some authors suggest factor loadings should be greater than .70 to be considered strong, Cabrera-Nguyen (2010) noted a “rule of thumb” that loadings less than .40 are weak, and those greater than .60 are strong.

Moreover, the Process Objectivity subscale ($\alpha = .64$), as well as the Product Objectivity subscales ($\alpha = .61$ and $\alpha = .54$ respectively) all exhibited lower internal consistency than the Depoliticization scale ($\alpha = .88$). However, Taber (2018) cautions researchers from interpreting alphas as a measure of the appropriateness or acceptability of a scale. First, Taber charted the large range of scores that are viewed as sufficient cited in science education literature, many of which the alphas in this study might exceed.

Additionally, Taber (2018) noted that researchers have justified using measures with low internal consistency since Cronbach’s alpha is informed by the number of items in the measure; however, increasing the number of items to improve the alpha may not be appropriate if it means including additional redundant items simply to improve alpha. Finally. Taber (2018, citing Cronbach’ 1951) noted that while high alphas might be desirable when assigning scores, as I do in this study, “the key point should be that scores obtained when using an instrument had to be interpretable,” and “instruments with quite a low value of alpha can still prove useful in some circumstances. In the quantitative strand, I used only the Process Objectivity subscale. However, the limitations and potential areas for improvement of this scale are an area for future work.

Following the scale validation process, I began developing individual profiles for each student based on their responses to ERB items at the start of the term. However, I returned to the original ERB scales during interviews with participants in the focal teams. In particular, I did not presume that students’ responses to ERB items in theory were an adequate reflection of their beliefs in practice, nor did I presume that modifications based on factor loadings and modification indices made my inferences about students’ individual beliefs any more or less accurate. Instead, I returned to the ERB scales at the end of the term to allow students to reflect on the items, discuss how their beliefs might have changed in light of their experiences, and describe any tensions students experienced while answering the questions. Their responses not only helped me evaluate the ERB scale, but also helped me understand some of the interactions I saw in team settings over the course of the project. I discuss this in further detail in the next chapters.

Table 5. Engineering-Related Beliefs Variables and Descriptive Statistics

Latent Variables/Variable Descriptions	Mean	Std. Dev.	Skewness	Kurtosis
Process Objectivity				
Engineers should rely on math and science when **defending** their ideas.	4.15	.81	-.93	4.06
Math and science are the best ways to defend ideas in engineering.	3.78	.91	-.77	3.08
If engineers follow mathematical and scientific principles, they will always find the best solutions.	3.04	1.09	-.03	1.89
Engineers should rely on math and science when **communicating** their ideas.	3.32	1.05	-.29	2.33
Product Objectivity				
Knowledge in engineering can always be proven true or false.	2.98	1.22	.10	1.99
Knowledge in engineering is objective.	3.24	1.00	-.17	2.28
Knowledge based in math and science is the most valid form of knowledge in engineering.	3.42	1.03	-.38	2.24
Theories in engineering cannot be argued or changed.	1.88	.91	1.01	3.58
Interpretations of engineering knowledge should not change from person to person.	2.33	.97	.44	2.41
Technical problems in engineering have only one right answer.	1.72	.92	1.37	4.52
Depoliticization				
Engineers should leave their personal beliefs out of their engineering work.	2.79	1.23	.13	1.95
Social justice concerns should not influence engineering work.	2.27	1.11	.73	2.91
Cultural beliefs should play no role in the creation of engineering knowledge.	2.71	1.20	.42	2.28
Engineers should leave their cultural beliefs out of their engineering work.	2.71	1.07	.34	2.37
Engineers should leave their personal opinions out of their engineering work.	2.74	1.08	.56	2.56
Political beliefs should not influence solutions to real-world engineering problems.	3.22	1.19	-.07	2.01

Table 6. Engineering-Related Beliefs Variables and Standardized Factor Loadings

Latent Variables/Variable Descriptions	Std. Estimate	SE	Std. Estimate/SE
Process Objectivity			
Engineers should rely on math and science when **defending** their ideas.	.480	.10	4.79
Math and science are the best ways to defend ideas in engineering.	.662	.08	8.30
If engineers follow mathematical and scientific principles, they will always find the best solutions.	.676	.08	9.07
Engineers should rely on math and science when **communicating** their ideas.	.422	.09	4.84
Product Objectivity A			
Knowledge in engineering can always be proven true or false.	.566	.07	7.78
Knowledge in engineering is objective.	.435	.08	5.27
Knowledge based in math and science is the most valid form of knowledge in engineering.	.747	.08	9.81
Product Objectivity B			
Theories in engineering cannot be argued or changed.	.460	.11	4.23
Interpretations of engineering knowledge should not change from person to person.	.676	.10	6.78
Technical problems in engineering have only one right answer.	.444	.10	4.43
Depoliticization			
Engineers should leave their personal beliefs out of their engineering work.	.761	.04	17.93
Social justice concerns should not influence engineering work.	.712	.05	14.19
Cultural beliefs should play no role in the creation of engineering knowledge.	.737	.06	12.73
Engineers should leave their cultural beliefs out of their engineering work.	.751	.05	15.55
Engineers should leave their personal opinions out of their engineering work.	.854	.04	22.88
Political beliefs should not influence solutions to real-world engineering problems.	.664	.05	12.41

Demographic Characteristics

Demographic data (i.e., race/ethnicity and gender) were gathered using institutional databases. Race/ethnicity variables were coded in numerous ways based on the University of Michigan's Learning Analytics Data Architecture (LARC) scheme. For example, individual racial/ethnic identity categories were initially coded dichotomously. Multiracial/multiethnic students might appear under multiple racial/ethnic categories. As a result, the LARC dataset also included dichotomous indicators for multiethnic students, minority students, and underrepresented minority students.

Sex, like the racial/ethnic categories, was also coded dichotomously. Students were asked to respond to an item indicating their "gender"[5] on the Beginning of Term Survey. In this study, male students were coded 0, while students who responded "female" were coded 1. Descriptive statistics for the study sample, as well as a comparison to prior terms of ENGR 100, and the College of Engineering more broadly, are presented in Table 7 below.

I wish to address three issues in the analysis of demographic data in this study. In Chapter 2, I critiqued the use of binary variables for understanding the role of racialized/gendered processes of marginalization. Coding sex dichotomously, for example, erases trans* students from discussions of gender in empirical analyses (Nicolazzo, 2015). Similarly, grouping Asian students with Hawaiian students, or grouping Latino/a, Black, and Native students together in a group called REM or URM erases the very real ways that racial hierarchy shapes the experiences of students in engineering. I acknowledge these issues; however, in later chapters, I discuss what we can learn by combining these coding schemes with rich qualitative, ethnographic research.

[5] While the item asked students to indicate their "gender," response options included included both indicators of sex (i.e., male, female) and gender (i.e., non-binary).

Table 7. Descriptive Statistics for Demographic Characteristics

	Survey Sample N (%)	College of Engineering N (%)
Sex		
Female	14 (25.4)	1,826 (28.1)
Male	45 (74.6)	4,669 (71.9)
Race/Ethnicity		
Asian America/Pacific Islander	20 (33.9)	1,295 (19.9)
Underrepresented Minority	5 (8.5)	179 (2.8)
White	37 (71.2)	3,178 (48.9)
Other	5 (8.5)	646 (9.9)
International Student Status	2 (3.4)	697 (10.7)
Underrepresented Minority Status	3 (5)	815 (12.5)

Notes: "Other" Students are those who indicated two or more racial identities or did not indicate a racial ethnic identity. Institutional data retrieved from publicly available enrollment reports for the 2019-2020 academic year. College of Engineering numbers represent only undergraduate enrollment. Institutional data sources use the term "Hispanic" and distinguishes "Hispanic" (i.e., self- identified as having Hispanic ethnicity) from "Hispanic or Latino" (i.e., self-identified as having Hispanic *or* Latino ethnicity based on federal data collection standards).

Group Communication Networks Survey

After the Beginning of Term survey, students received three surveys that were designed to collect data regarding their teamwork experiences over the course of the project—the Group Communication Survey, the Midterm Survey, and the End of Term Survey[6]. The first survey students received was the Group Communication Survey, which was the first survey after students were placed in their final design teams

As one of the goals of this research study was to understand factors influencing how students elevate or marginalize ideas during the design process, I chose the Group Communication Survey. At the start of ENGR 100, students were presented with the design problem and asked to produce an Individual Design Proposal. The Group Communication survey collected data at a time in each team in which students were all equipped with ideas for the

[6] While students responded to the End of Term survey as a requirement of the course, data from the End of Term survey was not used in this study.

project (i.e., via the Individual Design Proposal described earlier), but before the team had settled on ideas, particular perspectives were elevated or marginalized, and certain ideas discarded from the project.

Items measuring team contributions on The Group Communication Networks Survey were developed by the course instructors, in consultation with the Tandem development team. Some items were informed by the instructors' previous work using Comprehensive Assessment of Team Member Effectiveness (CATME) instrument developed by Ohland et al. (2014) rather than adapted from it. Other modifications were made in consultation with survey design experts through the University of Michigan's Center for Education Design, Evaluation, and Research (CEDER) to reduce the cognitive complexity of the instrument and address survey design issues (e.g., double-barreled questions).

Other items in the surveys, particularly those related to communication strategies and contributions to the team, were developed by the course instructional staff based on literature related to voice and voice enactment in organizational settings (e.g., Burris, 2012; Maynes & Podsakoff, 2014). Items were adapted to reflect the specific context of an engineering design team. For example, items related to the frequency with which individuals provide new ideas in Maynes and Podsakoff (2014) were modified to measure how often students in design teams contributed new ideas to the team's design process (e.g., "Daniel offered up most of the design ideas"). These items were incorporated into the self and team evaluations.

Additionally, course instructors developed items to measure individual contributions to the team's project across three broad design-related categories: (a) design tasks, (b) building tasks, and (c) communication tasks. These items are specific to the ENGR 100 course and ROV design project (e.g., asking students the degree to which they and their teammates contributed to "fabricating the custom part for the ROV). I utilize these measures of perceived contributions in the network analysis strand of this research (i.e., the contribution networks).

A critical aspect of any study utilizing a network analysis approach entails describing the nature of social relations (i.e., ties) within the network. Borgatti, Everett, and Johnson (2013) describe a taxonomy of social relations. In this study, ties represent perceptual relations between engineering students, instructors, and mentors about contributions over the course of the project. Thus, the Group Communications survey included items asking students for a self-evaluation and an evaluation of the teammates; specifically, students were asked the degree to which they believe they and each teammate "contributes ideas or perspectives" to the team (Appendix F). This item is measured on a five-point scale (i.e., 1 = "Never", 2 = "Rarely", 3 = "Sometimes", 4 = "Often", and 5 = "Always").

While I initially planned to analyze the ways that students drew on various sources of knowledge and ideas, such as instructors or students outside of their teams, my review of the quantitative data revealed that seeking help outside of the teams was rare. While some students reported help-seeking at the individual level (i.e., during the Individual Design Proposal), few reported help-seeking across teams. As a result, my analysis focused specifically on work *within* teams, reserving questions about help-seeking *across* teams for future research.

Midterm Networks Survey

Initially I planned to analyze only the Group Communications Network Survey data since (a) it was the most proximal survey to students' initial team meetings and (b) the ideas shared at the start of the project might shape the subsequent ideas that emerged over the course of the project. However, as I observed the focal teams and analyzed both qualitative and quantitative data, it became clear that the findings from my analysis of the contribution networks might not capture important dynamics about how students decided to pursue particular ideas in their teams. For example, ties in the initial networks represent perceptions that members of the team contributed ideas to the team's work. As I observed the focal teams, it became clear that the contribution of ideas was not necessarily disparate across the teams. Indeed, the instructional staff built in opportunities wherein each member was to have the opportunity to share at least the ideas they generated in their initial Individual Design Proposal. As a result, rather than focus the quantitative analysis on contributions alone, I analyzed the contributions that actually affected each team's project (i.e., enactments).

To do this, I analyzed a second set of team networks from the Midterm Networks Survey (Appendix G). The Midterm Networks Survey was administered following the team's Detailed Design Review presentations. Unlike the Group Communication Networks Survey, where teams had only had initial meetings to share, negotiate, and consolidate ideas, the Midterm Networks Survey occurred after teams began to narrow their initial concepts into a final ROV design. As a result, while many of the items on the Midterm Networks Survey were identical to those from the Group Communications Network Surveys (e.g., self- and teammate evaluations of contributions), additional items could provide whether particular contributions might have been systematically maligned or discarded. In particular, the survey asked students to rate the degree to which their own and their teammates' ideas were "enacted"[7] in the team. The item was measured on a 9-point bipolar scale, where 1 (i.e., "Our assignments didn't include many ideas from [Team Member]") indicated a lack of influence over the design process and 9 (i.e., "Many

[7] The term "enacted" is one used by the ENGR 100 instructional staff, referring to whether the ideas put forth by particular team members were actually included in the team's work. It might be the case, for example, that while all members of a team contributed ideas, only one influential actor's ideas were enacted by the team.

of [Team Member's] ideas were used in our assignment) indicated *influence* over the team's design.

Data Analysis

Qualitative Data Analysis

According to Creswell and Clark (2017), in convergent designs researchers collect both qualitative and quantitative data simultaneously. These two sources of data are first analyzed separately, followed by a merging process wherein data from the two strands are either compared or transformed for further analysis (Cresswell & Clark, 2017). In this section, I describe the data analysis process for the qualitative strand of this study, as well as how the analysis process addressed each research question.

Ethnographic Fieldnotes and Reflective Journals

A central, defining purpose of ethnographic research is cultural description and analysis, where culture is defined as "the totality of all learned social behavior of a given group" that "provides the systems of standards for perceiving, believing, evaluating, and acting" (Thomas, 1991, p. 12). Since the first research question (i.e., "To what extent do students' understandings of engineering knowledge and engineering work reflect Eurocentric epistemic values in engineering?") centers on describing the epistemic culture and how students might come to enact it, I began the qualitative analyses by revisiting fieldnotes and my reflective journal.

Emerson, Fretz, and Shaw (1995) describe a systematic process by which ethnographers use fieldnotes to facilitate coherent analyses. First, the ethnographer reads all fieldnotes in order to "elaborate and refine earlier insights and lines of analysis by subjecting this broader collection of fieldnotes to close, intensive reflection and analysis" (p. 172). Thus, I began by reading my entire corpus of field notes and journals.

Revisiting my fieldnotes prior to the iterative process of coding was particularly useful for identifying patterns, relating particular incidents over the course of the term to each other, or dispelling early notions that I documented in my fieldnotes or reflective journal in light of new evidence. For example, at the start of the term, I noticed a particularly awkward interaction between a male student in a focal team and one of the women on the instructional team. As I documented the observation, I wondered how gender had played a role, and if I might see other evidence that gender had shaped this interaction:

> [Female Instructor] asked several students to move to a table so that they might work in teams. One student, [Male Student], had what I perceived to be a tense interaction with [Female Instructor]. [NOTE: Later, [Female Instructor] confirmed that she also perceived the interaction to be tense]. [Male Student] let out a light but audible exhale that both [Female Instructor] [confirmed later] and I perceived to be a sign that he was clearly annoyed by [Female Instructor]'s request. [Female Instructor] and I met eyes as this happened. [NOTE: The meeting of the eyes here, in my view, was a mutual acknowledgement of the "weirdness" of the interaction. [Male Student]'s response was so subtle, that [Female Instructor]'s look felt more like a "Are you interpreting this the same way that I am?" and my glance back was an affirmation] [NOTE: I wonder if this is a sign of gendered opposition to come, given what I perceive to be disrespect from [Male Student] to [Female Instructor].

Returning to this incident following data collection, but before the coding process allowed me to put the incident in richer context and changed how I coded the observation. For example, at the end of the term, following interviews and observations, I learned that what I had perceived as potentially sexist disrespect from the male student was actually a deep discomfort with social engagement, particularly in teams. This helped frame the codes I used during the coding process.

Following my review of my fieldnotes, I engaged in an iterative process of coding fieldnotes. In developing a codebook consisting of a priori codes to capture the sensitizing concepts used to describe the dominant epistemic culture of engineering as described in the previous sections (i.e., objectivity, neutrality, depoliticization) as well those posited by SCT (i.e., action opportunities, performance outputs and evaluations, influence). The full codebook is in Appendix H. I began by using the a priori codes to code an initial set of five team meetings and 3 interviews. As I coded these initial meetings and interviews, I added new codes and re-coded each of the initial meetings and interviews. I continued this process until "coding seemed to generate no new ideas, themes, or issues" (Emerson et al., 1995).

Finally, I documented the reading and coding processes, and ideas, themes, and descriptions I developed during the coding and analysis process in memos. Miles, Huberman, and Saldana (2013) describe memoing as a way of documenting thoughts that occur throughout the data collection, analysis, and reporting process. Analytic memos are a way to "'dump your brain' about the participants, phenomenon, or process under investigation by thinking and thus writing, and thus thinking even more about them" (Saldana, 2009, p. 32). In analytic memos, researchers reflect on their personal relations to participants, emergent patterns and themes, personal or ethical dilemmas, links amongst the codes, and future directions for the study (Saldana, 2009). Writing reflective and analytical memos was an ongoing process as I analyzed fieldnotes. Over time, I returned to memos to elaborate on ideas, or put ideas in richer context given other analytic memos or analyses, as I analyzed further data. In particular, as relevant patterns occurred across individuals and teams, I began to develop memos documenting these patterns, which ultimately became the findings discussed in later chapters.

In my initial analytic memos, I reflected on how I personally related to these observations (Saldana, 2009). I also used analytic memos to compare sources of data throughout this study. For example, CRT literature, as well as literature on the philosophy of technology, suggests that the dominant epistemic values of the discipline are mythical ideals, and that while some engineers may use non-scientific knowledge (e.g., experiential knowledge, folk theories) (Norstrom, 2013), adherence to scientific objective, neutrality, and the ideology of depoliticization might operate to keep other students from using non-scientific knowledge. Thus, I compared students' responses to survey items to the ways these values might be enacted in design settings using analytic memos. Finally, writing, visiting, and revisiting analytic memos was a way to facilitate a richer understanding of the data during this study.

Design Experience Interviews

I engaged in a similar process for analyzing interview data. First, I transcribed the audio recordings of interviews using a third-party transcription service. I began the process of coding using a priori codes based on my conceptual framework and similar to those described in the previous section. As I engaged in this initial coding process, I similarly added to the existing codebook as I read and reread interview transcripts. I continued this process until I generated no new codes.

Following the interview coding process, I began to relate observations from my fieldnotes to students' descriptions and interpretations from their respective one-on-one interviews. Here, I engaged in subjectivist reflexivity—self critique—where I noted places in which students' reflections on particular incidents aligned or diverged from my own interpretations. An example of this occurred in an episode I documented in my fieldnotes, in which I wondered what role gender had played in a rather tense meeting on one of the focal teams:

> I noticed Stephanie and Ryan clash multiple times during the lab session. At one point, Stephanie was speaking to the team attempting to delegate building tasks for the concept vessel. Ryan interrupted to offer a plan of his own. Stephanie interjected, "Stop. STOP!" to get the floor back from Ryan. Stephanie then negotiated with Rehman: "You guys (Danish and Rehman) finish the first half and we (Lauren, Stephanie, and Ryan) will

> finish the back. Danish and Rehman then began working together, creating a familiar gendered divide on the team. This gender divide has become a theme.

I returned to this incident with each member of Team Surge to gather their understanding of both the moment, as well as their perspectives about the role that gender might have played the interaction. Whereas my initial interpretation was, at best, a value-laden best-guess, which led me to question whether or not to code this excerpt using the "salience of gender" code, returning to the incident and asking students to explicitly reflect on the role gender might have played in this interaction helped put my observation in richer context. As a result, I re-coded the incident as a moment in which gender informed the design process.

Finally, I read through students' understanding of engineering work and my own conclusions about their understandings, as documented in fieldnotes, journals, and memos, simultaneously to understand how my understanding of the context of engineering might differ from students currently experiencing engineering education. I engaged in this practice to honor the *critical* aspect of this critical ethnography. Thomas (1991) notes that critical ethnography entails making value-laden judgements of meaning, and that while conventional ethnographers speak *for* their participants, critical ethnographers speak *to* an audience on behalf of participants. Thus, I do not suggest that I honored students' perspectives and meaning above my own. Indeed, as I wrote in the positionality section, my current understanding of how race and racism informed my own first-year design experience is the result of years of reflection, as well as a scholarly endeavor that facilitated an analysis, and re-analysis, of my first-year design experience. Rather, in the Findings presented in the following chapters, I "own" places where I am making value-laden judgements that might make my understanding of my observations differ from those provided by students.

Peer Mentor Journals

Finally, I coded peer mentor journals using a process similar to the Design Experience Interviews. I read and reread journals, coding particularly for the four behavioral sequences described by SCT. Moreover, I developed additional codes related to descriptions of dynamics that I ask peer mentors to reflect on. Since data from peer mentors provided information on teams that I do not directly observe, I coded broad team dynamics, as well as comments about individuals, in order to include peer mentor perspectives in my discussion of the networks data. I did this, in part, to help put quantitative results in descriptive context. For example, similar quantitative results in two different teams might be the result of two different teamwork processes (e.g., There is no tie from Sarah to Tom on Team A because Tom shows up, but does not contribute, while there is no tie between Jack and Jim on Team B because Jim never shows up). This is the merging process that Creswell and Clark (2017) describe in their descriptions of convergent designs in research.

Trustworthiness and Validity

I engaged in a number of methodological processes in order to address threats to validity and ensure trustworthiness, some of which have been mentioned in other sections. While acknowledging that "methods and procedures do not guarantee validity," Maxwell (2013, p. 125) outlined several strategies for addressing validity threats, which I employed in this study. For example, Maxwell argued that intensive, long-term involvement using repeated observations, interviews, and sustained presence in the setting can allow a researcher check and confirm inferences. During this study, I engaged in repeated observations, interviews, and used reflective memos and journals to return to clarify inferences during the study. I participated in reflexive engagement during which I returned to my observations, clarified ideas in light of new observations and evidence, as well as acknowledged assumptions, falsified presuppositions, and documented new interpretations of the data.

I also engaged in a process of respondent validation, or member checking. According to Maxwell (2013), member checking entails “systematically soliciting feedback about your data and conclusions from the people you are studying” (p. 126). I engaged in respondent validation during one-on-one interviews, in which I discussed preliminary interpretations and findings with each student in the focal teams in order to assess their sense- and meaning-making about particular incidents over the course of the term, as well as to confirm, correct, or supplement my own understanding, recognizing that first-year engineers were unlikely to express their beliefs in terms like “Eurocentric epistemologies” and “epistemic racism.” I also allowed students opportunities to read preliminary assessments of themselves, their respective teams, and themselves within the context of their team, during the member checking portion of the interview.

I also engaged in a triangulation, which Denzin (1989) defined as “the combination of methodologies in the study of the same phenomenon” (p. 234). According to Maxwell (2013), triangulation enhances validity by “reducing the risk of chance associations and of systemic biases due to a specific method” (p. 128). Denzin outlined four types of triangulation—data, investigator, theory, and methodological triangulation—of which I engaged in two. First, I engaged in data triangulation, which entails collecting data from multiple data sources (Denzin, 1989). I was purposeful in selected three different focal teams that varied in their demographic makeup. I also engaged in between-method methodological triangulation, which “combines dissimilar methods to illuminate the same class of phenomenon” (Denzin, 1989, p. 244). In this study, I examine the role of dominant epistemologies using participant observations, interview, survey data, and network analysis.

Finally, I searched for discrepant evidence by describing instances in which my observations, interviews, or quantitative findings deviated from my conceptual framework. In Chapter 2, I described a set of propositions guided by Critical Race Theory, Status Characteristics Theory, and theoretical assumptions about how dominant epistemologies might shape hierarchies and behaviors in design teams. Over the next several chapters, I describe moments that appeared to falsify those propositions, and describe the implications of those moments for theory and research on engineering design teams.

Quantitative Data Analysis

Missing Data

The online surveys in ENGR 100 were a graded assignment; however, over the course of the project, several students failed to submit one or more of the surveys. As a result, I utilized several strategies for handling missing data. First 59 of the 59 students in the class submitted the Beginning of Term survey, and there was no missing data for items measuring engineering-related beliefs. However, six of the 59 students did not submit the Group Communication Networks Survey from which the self- and peer-evaluation data were derived.

Since students were asked to respond to similar items over the course of the term in multiple surveys (e.g., the Midterm Survey and End of Term Survey), the most proximal responses to relevant items were used. If, for example, a student did not submit a Group Communication Network Survey, but that student submitted the next survey—the Midterm Survey—I used that student's responses on the Midterm Survey in the quantitative analysis. This accounted for five of the 6 missing responses. For the final student in the network, who submitted Engineering-Related Beliefs data at the start of the term but no self-and peer evaluations, self and peer evaluations were replaced with means at the team level (i.e., the means of team responses).

Describing the Networks

In this study, each team is modeled using two networks henceforth referred to as the “Contribution Network” and the “Enactment Network.” Ties in each team’s contribution network represent perceptions that a particular team member is contributing ideas to the team’s work. Recall that the item measuring contributions was measured on a 5-point Likert-type scale (i.e., 1 = “Never”, 2 = “Rarely”, 3 = “Sometimes”, 4 = “Often”, and 5 = “Always”). For this analysis ties between students in each team represent perceptions that teammates “often” or “always” contribute ideas to the team.

Ties in the enactment network represents perceptions that a particular team member’s ideas are actually enacted by the team. Recall that the enactment item was measured on a 9-point likert scale, where 1 indicated a perception that the team did not use a student’s ideas while 9 indicated the team used many of a student’s ideas during the design process, an indicator of influence in the teams. In this study, ties in the enactment network represent perceptions of frequent enactment of a student’s ideas. Since the average value of perceptions self- and teammate enactment in the dataset was approximately 7, the absence of a tie indicates that a student’s ideas were utilized by their team less than the ideas of other students in the course, on average (i.e., 6 or less on the scale).

Descriptive Analyses

I began the quantitative analysis by conducting descriptive analyses of the structure of the contribution and enactment networks of all 12 teams in ENGR 100. First, I developed descriptive profiles of the 59 students in ENGR 100 by analyzing responses to the engineering-related beliefs survey described in the previous sections (see Appendix I), as well as responses to items related to self and team evaluations of contributions to design tasks on the team. Since this research is primarily concerned with the design process and the ways in which students elevated or marginalized ideas, the first descriptive analyses focused primarily on patterns related to whose ideas were acknowledged on the team and by whom. Moreover, since my research questions focus on the ways students understand knowledge in the process of engineering design, I used the *process objectivity* factor as a covariate of interest in the quantitative analysis.

Second, I operationalized characteristics of the 12 teams using networks concepts. For example, Novoselich and Knight (2018) characterized shared leadership in terms of network centralization and density. Centralization, which refers to the degree to which a network (i.e., design team) is dominated by a single node (i.e., student in a team), is one preliminary measure of cohesion and influence on the teams (Borgatti, Everett, & Johnson, 2013). To compute network centralization, I first computed the in-degree centrality for each student in each team. In-degree centrality represents the number of *incoming* ties and is often one way to operationalize popularity, prestige, or leadership in a network, to name a few (Borgatti et al., 2013). In this study, in-degree centrality represents the students who is more widely perceived to be contributing ideas (i.e., contribution networks) and whose ideas are perceived to be more frequently utilized by the team (i.e., enactment networks).

Another network-level (i.e., team-level) measure is density. Density is "perhaps the simplest measure of cohesion" and is the proportion of ties in the network to *possible* ties in a network (Borgatti, Everett, & Johnson, 2013, p. 150). Importantly, the characteristic of the team operationalized in network concepts depends on the relationships captured in network ties. In the contribution networks, since ties were perceptual ties representing contributions of ideas to the team, a density of 1 suggests all students contributed ideas to the team's design, and that those ideas were recognized by their teammates (i.e., shared contributions). The unlikely density of 0 suggests no students contributed ideas to the team's ROV design. Similarly, in the enactment networks, a density of 1 suggests all students' ideas are influencing the team's ROV design.

As Borgatti et al. (2013) note, these descriptive measures are best used in comparative ways—comparing the same network at various times or comparing similar networks at once. Whether a particular density should be considered high or low depends on the context and nature of relationships. Accordingly, I began by comparing the contribution and enactment networks for the 12 teams in the course. Additionally, I compared and contrasted the 12 teams by examining the contribution networks, enactment networks, and changes between the contribution and enactment networks, for each of the 12 teams in the study, comparing these descriptive measures across the teams to develop an understanding of the both the nature of working relationships *within* teams, and the relative structure of contributions *across* teams.

Second, I used node- (i.e., individual student), dyad-level (i.e., pairs of students), and triad-level analyses as preliminary indicators of patterns in teams. For example, I conceptualized in-degree centrality—measuring the number of incoming ties—as a preliminary measure of influence on a team. In the contribution networks, a student whose in-degree centrality is high relative to others on the team is perceived to be contributing more or having their contributions to the team more widely recognized than other team members. In the enactment network, a student's who's in-degree centrality is high relative to other students on the team is having their ideas enacted more frequently than other members of the team. I developed graphical representations of the teams in this study to reflect relative influence in the teams, as reflected by students' in-degree centrality in each of the 12 teams (see Chapter 7).

Multilayer Exponential Random Graph Models

While descriptive analyses provided preliminary assessments of each of the 12 teams in the study, these analyses are limited in that they do might not adequately represent the underlying nature of working relationships within and across the teams. It is possible, for example, that two teams with similar centralization or density metrics exhibit very different underlying working dynamics. As a result, I used a multilayer exponential random graph model (i.e., multilayer ERGM) to examine the structures of working relationships across the 12 teams in the study, as well as the relationships between contributions and enactments in the 12 teams.

Exponential random graph models (ERGMs), of which multilayer ERGMs are an extension, are a family of statistical models used to examine theoretical models of network generating processes. Goodreau and colleagues (2009) compared the ERGM to standard logistic regression models. In this analogy, the outcome of interest is the probability of a tie between two nodes in the network (Chen, 2019; Cranmer & Desmarais, 2013), and "the predictors are things like 'propensity for individuals of the same sex to form partnerships' or 'propensity for individuals to form triangles of partnerships" (Hunter et al., 2008a, p. 2) and exogenous covariates (e.g., race/ethnicity, gender, epistemological beliefs as measured in the ERB scale). ERGMs are particularly useful because they can be used to examine the effects of exogenous covariates, as well as endogenous dependence terms—the structural relationships between the ties themselves—simultaneously (Cranmer & Desmarais, 2011). Goodreau et al. (2009) offer the general form of the ERGM as:

$$P(Y = y|n) = \frac{\exp\left(\sum_{k=1}^{K} \theta_k z_k(y)\right)}{c}$$

Here, $P(Y = y|n)$ is the probability of the set of ties, Y, given *n* students, θ_k is the vector of coefficients that represent the effect of each parameter in the model, $z_k(y)$ represent the model covariates, and *c* is the normalizer (i.e., the numerator summed over all possible networks with *n* students) that ensures the probabilities sum to 1.

As Borgatti, Everett, and Johnson (2013) write, the issue for the researcher in specifying the ERGM is the set of configurations, called dependence terms, to select for the model. Here, dependence terms represent theories underlying the relationships between the ties in the network (Cranmer & Desmarais, 2011). The selection of dependence terms is guided, in part, by assumptions about the data, as well as the theory, hypotheses, and propositions guiding the research (Borgatti et al., 20113; Cranmer & Desmarais, 2011). For example, in this study, Proposition 4 suggests students who elevate Eurocentric epistemologies will wield greater influence in their teams, here represented by perceptions of contributions and enactments. As a result, a dependence term capturing the role of Eurocentric epistemologies in elevating contributions and enactments is included in the model (i.e., in-degree popularity term). Similarly, because I was interested in the relationships between other exogenous covariates (i.e., race/ethnicity, gender) and the degree to which particular students' ideas were elevated or marginalized on their teams, I included terms capturing the effects of these covariates on in-degree.

Generally, ERGMs have been used to examine monoplex networks—networks where ties represent a single type of social relationship (Chen, 2019). However, in this study, the 12 ENGR 100 design teams are represented as multiplex networks—networks where ties represent two or more relationships (i.e., contributions and enactments). A graphical representation of the two relationships in both the three focal teams (i.e., Team Mobula, Team Surge, and the Yachtsmen), as well as the non-focal teams, can be found in Figure 2 below. Moreover, side-by-side comparisons of each team's contribution and enactment network can be found in Appendix J.

Traditional approaches to statistical inferences on the networks in this study might include at least two different models—one model examining idea contributions and a second model examining idea enactments. Another approach might entail analyzing idea enactments alone, using idea contributions as an exogenous covariate underlying perceptions of enactments. Other approaches might utilize 24 different models—one model per team per relationship—aggregating results for statistical inferences. However, these approaches are limited in multiple ways.

First, modeling idea contributions and idea enactments separately ignores the relationships between the two social processes and questions that might arise as a result. For example, one might guess that a student who is perceived to frequently contribute ideas might also be perceived to have those ideas enacted more often as a result. Even models utilizing one relationship (e.g., idea contributions) as an exogenous covariate underlying relationship (e.g., idea enactments) are limited because such an approach does not model the potentially different social processes underlying the structure of idea contributions. Instead, the multilayer extension of the ERGM allows for analyzing both layers (i.e., idea contributions and idea enactments) while differentiating between the two potentially different social processes underlying each layer (Chen, 2019). As such, I employ the multilayer ERGM for statistical inferences on design teams, where each team is represented by two relationships—perceptions of idea contributions and perceptions of idea enactments.

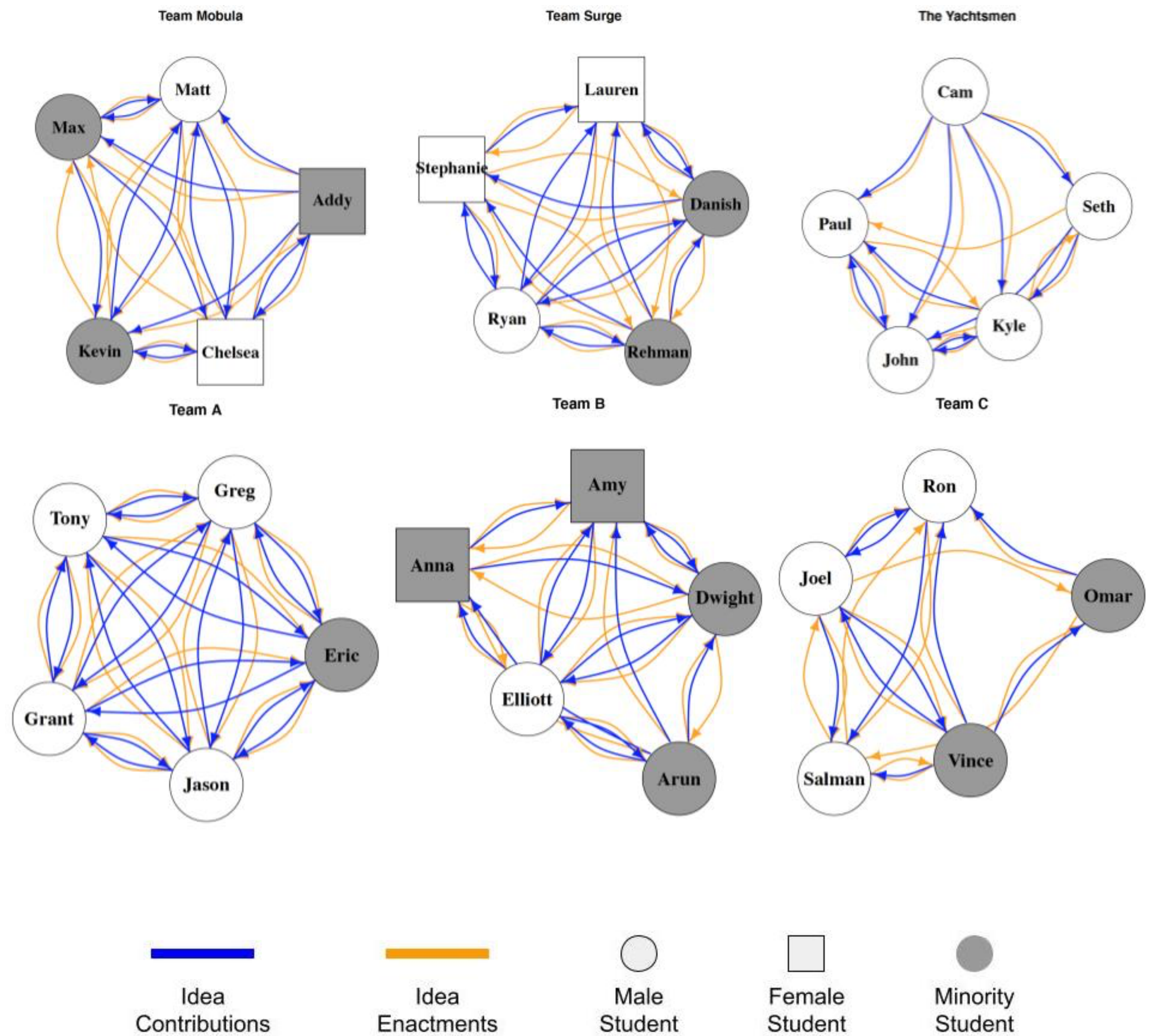


Figure 2. Graphical representation of idea contributions and enactments in ENGR 100 teams.

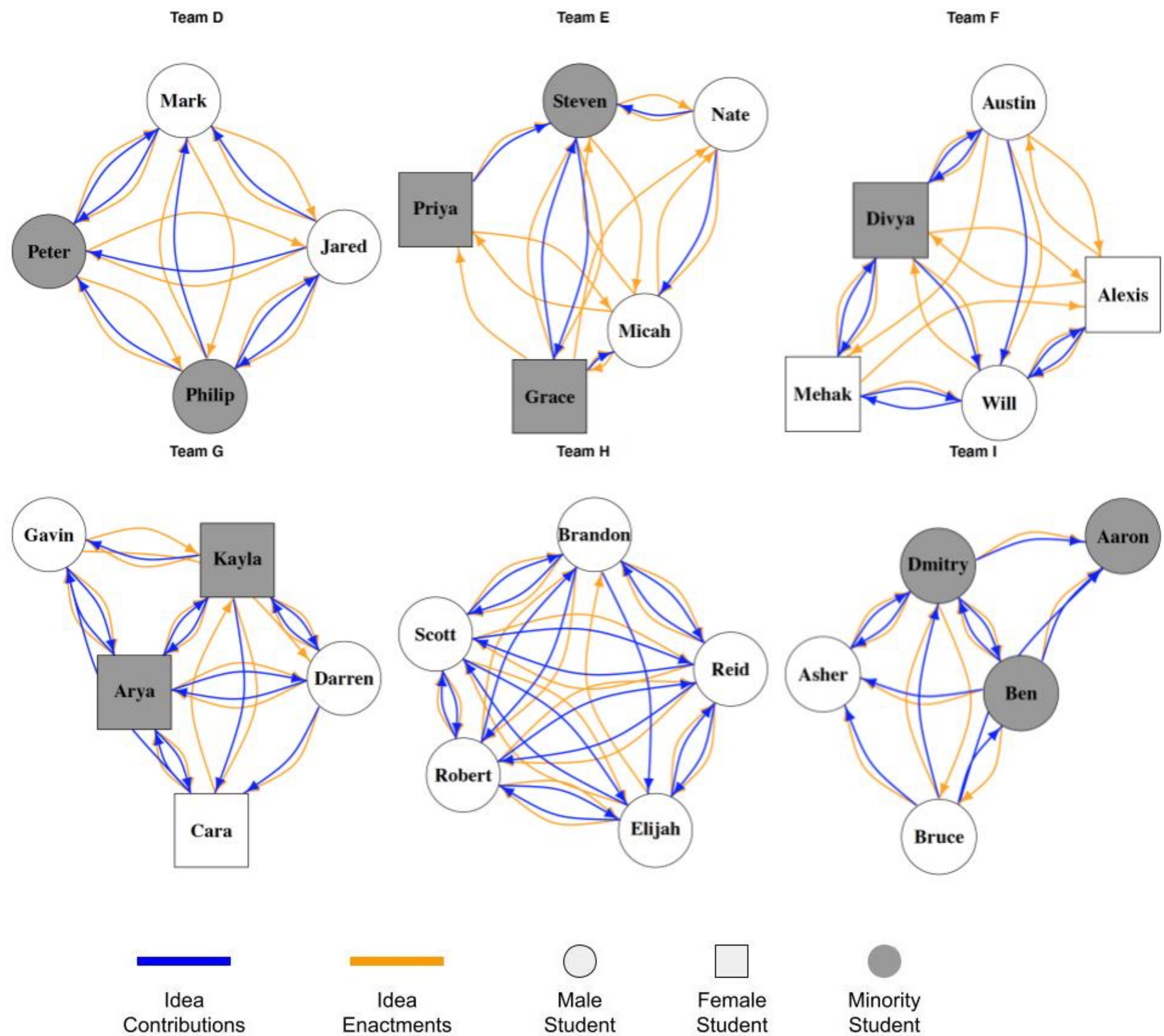


Figure 2 (cont).

In addition, the multilayer extension of the ERGM is used to examine other cross-layer dependence structures (i.e., network generating processes *between* the two types of ties) (Chen, 2019). Just as dependence terms in ERGMs on monoplex networks "capture theories postulating relationships among the ties in a network" (Cranmer & Desmarais, 2011, p. 67), cross-layer dependence terms capture theories about the relationships between contributions and enactments and exogenous covariates (i.e., race/ethnicity, gender, and epistemological beliefs) that might influence in those relationships.

I used the multilayer.ergm package in R developed by Chen (2019) to analyze these multiplex networks, which entails both specifying theoretically purposeful within- and cross-layer configurations, as well as applying appropriate sampling constraints. The sampling constraints represent the characteristics of the networks that require ties never be formed in the network. Sampling constraints, "usually in the form of disallowing ties to be formed between certain nodes" (p. 6), in this study represent the impossibility of students on different teams reporting idea contributions and enactments for each other. That is, in this study, constraints were applied such that ties across teams (e.g., between Team Surge and Team Mobula) were disallowed. No other sampling constraints were applied in the model.

Additionally, just as Borgatti, Everett, and Johnson (2013) described the selection of configurations as a key process for specifying ERGMs in monoplex networks, Chen (2019) described the selection of model terms, including both intralayer terms and cross-layer dependence structures for multiplex networks, as a key consideration for specifying multilayer ERGMs. Krivitsky (2012) describes the different propensities for individuals to develop social ties as a key feature of social networks. In the networks strand of this study, a key question for examination is the different propensity for individual students to be seen as frequent contributors, as well as the varying propensity for particular students to have their ideas enacted in their teams. Since this research was concerned with the role of status characteristics (i.e., race/ethnicity, gender, and epistemological beliefs) in idea contributions and enactments, I included three intralayer terms—popularity, sociality, and homophily—in the model to capture how race/ethnicity, gender, and epistemological beliefs might shape idea contributions and enactments in teams.

Popularity effects, also called *receiver* effects, are actor-specific (i.e., student-specific) terms that represents the probability that a student will be reported as a frequent idea contributor (i.e., layer 1), as well as the probability that a student's ideas were enacted (i.e., layer 2) on their teams, based on an exogenous covariate specified in the model. I included three popularity effects in the model consistent with the theoretical perspectives guiding the study—race/ethnicity, gender, and epistemological beliefs (i.e., process objectivity scores), as measured by the ERB scale.

Similarly, sociality effects, also called *sender* effects, are actor-specific terms that represent the probability that a student will report other students as frequent contributors based on an exogenous covariate specified in the model. Like the popularity effects, I included three sociality effects in the model related to race/ethnicity, gender, and epistemological beliefs. I include these terms because existing research suggests race and gender might shape social relationships in networks.

Finally, homophily effects, represent the tendency for students to nominate other students who share a characteristic (e.g., race/ethnicity, gender category). As I did for both the popularity and sociality effects, I included three homophily terms related to race/ethnicity, gender, and epistemological beliefs. Additionally, a similarity term for the quantitative ERB measure utilized the distances (i.e., arithmetic difference) between students' respective ERB scores. Kim and colleagues (2016) argued "this approach is analogous to including both main effect and interaction effects in a regression" (p. 30), where the main effect is captured by the propensity for students of particular racial/ethnic or gender categories to send or receive ties and the interaction effect is captured by terms that examine whether students who share a racial/ethnic or gender category are more likely to share a tie. Table 8 below provides an overview of the terms included in the model.

Table 8. Model Terms and Definitions for Intralayer Terms

Model Term	statnet term	Definition
Popularity Effects (Categorical)	nodeifactor	Represents the probability that a student would be nominated as a contributor of ideas (i.e., layer 1), or that a student's ideas were perceived to be frequently utilized (i.e., layer 2), based on a *categorical* covariate (i.e., race/ethnicity, gender).
Popularity Effects (Quantitative)	nodeicov	Represents the probability that a student would be nominated as a contributor of ideas (i.e., layer 1), or that a student's ideas were perceived to be frequently utilized (i.e., layer 2), based on a *quantitative* covariate (i.e., ERB scores).
Sociality Effects (Categorical)	nodeofactor	Represents the probability that a student would nominate other teammates as contributors of ideas (i.e., layer 1), or as having their ideas frequently enacted (i.e., layer 2), based on a *categorical* covariate (i.e., race/ethnicity, gender).
Sociality Effects (Quantitative)	nodeocov	Represents the probability that a student would nominate other teammates as contributors of ideas (i.e., layer 1), or as having their ideas frequently enacted (i.e., layer 2), based on a *quantitative* covariate (i.e., ERB scores).
Homophily	nodematch	Represents the probability that of a tie between teammates who share a *categorical* covariate (i.e., race/ethnicity, gender) on the contribution (i.e., layer 1) or enactment (i.e., layer 2) layers.
Similarity	edgecov	Represents the probability of a tie between teammates who are similar on a *quantitative* covariate (i.e., ERB scores) on the contributions (i.e., layer 1) or enactments (i.e., layer 2) layers.

Notes: In the multilayer.ergm package developed by Chen (2019), each popularity, sociality, and homophily term is specified for each layer. For example, nodeifactor in statnet is nodeifactory_layer in multilayer.ergm, where the layer is specified as 1 (i.e., idea contributions) or 2 (i.e., idea enactments).

Additionally, Chen (2019) described 10 observable dyad-level cross-layer dependence structures than can be modeled in multilayer-ERGMs (Figure 4). The tenth configuration, which Chen (2019) called the "empty actor-dyad" (p. 11) is not shown in Figure 3.

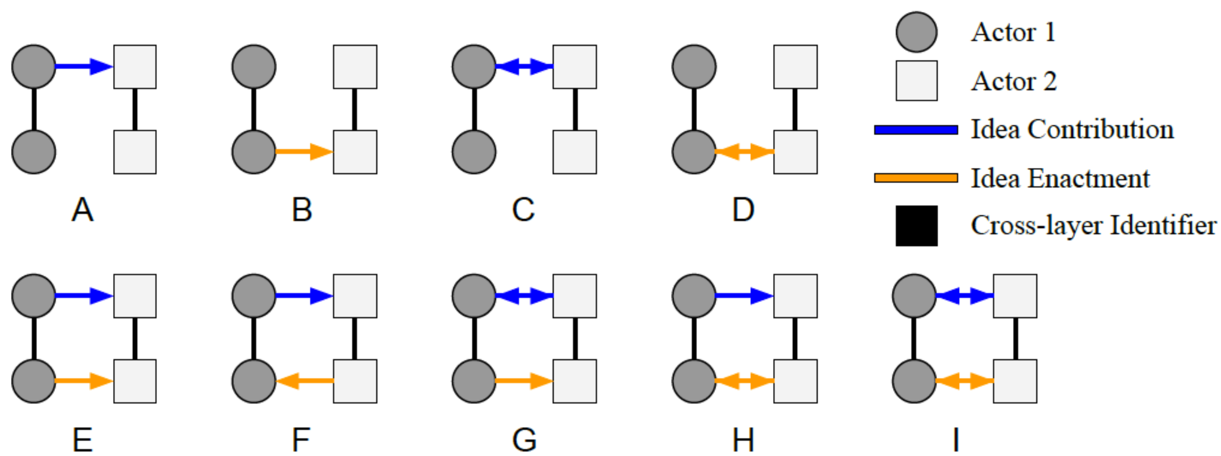


Figure 3. Census of dyad configurations in a directed network presented by Chen (2019) and modified to represent the multiplex networks analyzed in this research.

In this study, I chose four theoretically purposeful dyad configurations to model in the multilayer ERGM. Each configuration was selected to represent the potential for processes of inequity on design teams. For example, configuration E, which Chen (2019) refers to as the cross-layer reinforcement term, captures the tendency for those members of the design team reported as idea contributors to also be identified as those members who have their ideas enacted in design teams.

Chen (2019) suggests configurations G, H, and I "represent complex forms of conditional reciprocity." However, I suggest that in this study, these terms might be indicators of patterns of inequity on teams. For example, I included a term representing Configuration G, which I called the "marginalization/elevation" term. Configuration G captures the hypothesis that equal idea contribution may not result in equal idea enactment. I also included a term representing Configuration H, which might help capture tendencies to infrequently contribute ideas, but to still have those ideas elevated. Finally, I included a term for Configuration I, which I called the "mutual contribution" term. Configuration I captures shared contributions and enactments at the dyad level on the teams.

Finally, a variety of methods for assessing ERGMs are common in the literature. First, I assessed the goodness-of-fit by assessing goodness of fit plots, which can be found in Appendix K. Second, I assessed degeneracy diagnostics, including the trace and density plots, which can be found in Appendix K, as well as MCMC convergence diagnostics (e.g., Geweke Diagnostics). I found the that the model fit the in-degree, out-degree, and edgewise shared partners distributions well (see Appendix K). Moreover, I found the model was not degenerate.

My goal in this analysis was to position the findings from the network analysis of the teams alongside the findings of the critical ethnography to understand the working processes within both the focal and non-focal teams. In the next section, I describe how I synthesized these data to answer the research questions, as well as address the propositions stated in Chapter 2.

Synthesizing the Qualitative and Quantitative Strands

Finally, as this is a convergent design, I describe the merging process wherein data from the both the qualitative ethnographic and the quantitative networks strands are either compared or transformed for further analysis (Cresswell & Clark, 2017). In this section, I first describe the data analysis process for the qualitative and quantitative strands, followed by my process for synthesizing data collected in each strand. A procedural diagram positioning the data in the two strands can be found in Figure 4 below.

Research Question One

Recall that the first research question entails understanding how Eurocentric epistemologies (i.e., scientific objectivity, value-neutrality, and the ideology of depoliticization) shape the ideas students consider, pursue, and discard individually and in teams. To answer this question, I combined and analyzed data at the individual level by developing descriptive profiles of the students in the focal teams. To develop these profiles, I drew on the students' beliefs using

(a) responses to the engineering-related beliefs items on the Beginning-of-Term survey, (b) observations of the design process throughout the semester, and (c) students' descriptions of their beliefs and behaviors during their respective one-on-one interviews. I compared students' stated beliefs, as reflected in their responses to survey items, to the ways in which they described engineering and the ways that they described engineering work following the project in order to ascertain how their views on Eurocentric epistemic values might have changed over the course of the project.

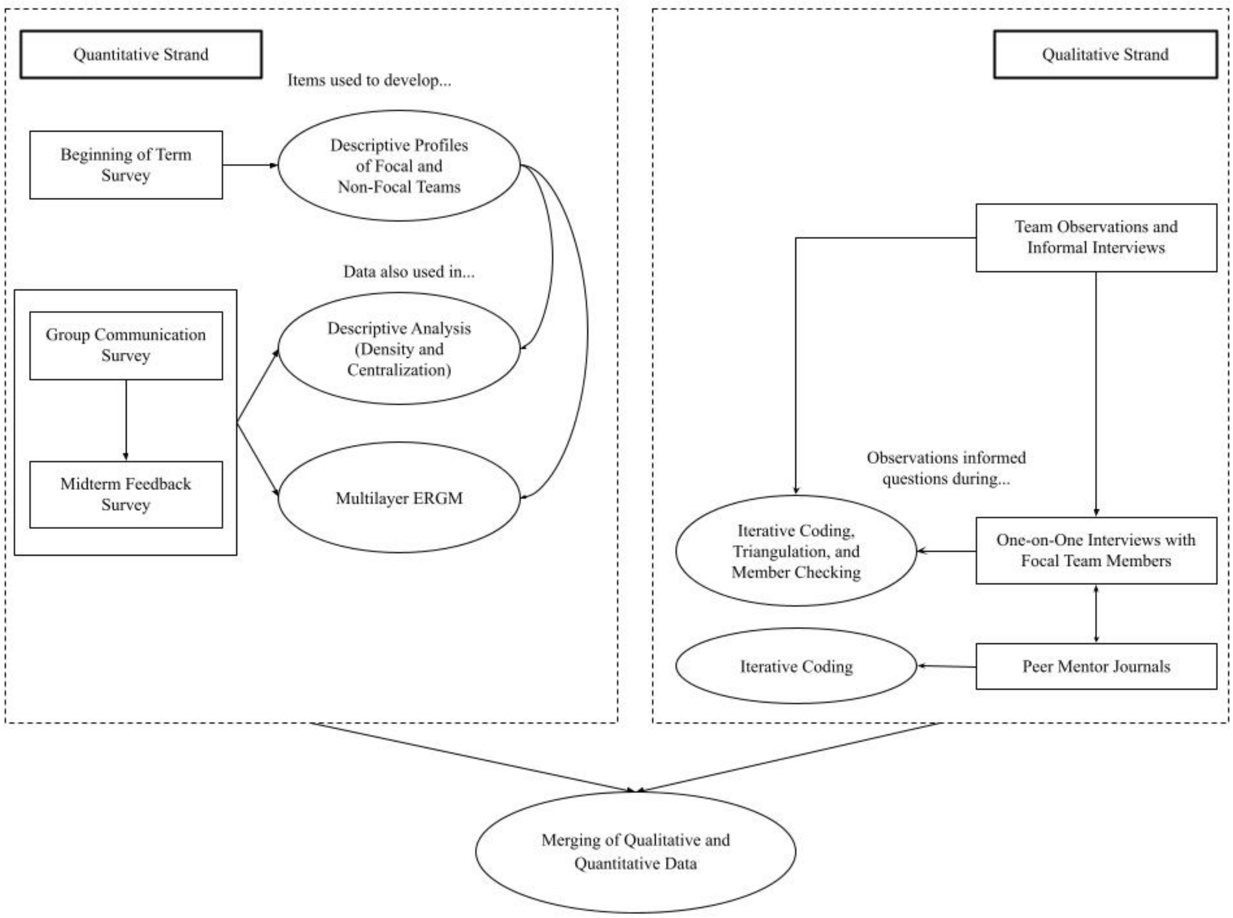


Figure 4. Procedural diagram of qualitative and quantitative study components.

In the qualitative strand, I also drew on data from one-on-one interviews during which students described the sources and support for both their individual ideas, as well as how their teams pursued or discarded particular ideas in their teams. I documented the ways that students described presenting their ideas to their teams, including the types of knowledge they drew to support their ideas and, importantly, *why* they relied on particular sources of knowledge when communicating their ideas.

Research Question Two

The second research question entails understanding how Eurocentric epistemologies influence interactions and status hierarchies in teams. To answer this question, I drew on the (a) descriptive analyses from the network analysis strand, (b) journal data from peer mentors, and (c) fieldnotes and reflective memos from my observations throughout the semester. I *combined* measures of influence (i.e., reports of contributions and enactments) from the Group Communication Network Survey in the quantitative strand with descriptions of team dynamics as provided by peer mentors for the non-focal teams and that I observed in the focal teams to understand the role of epistemological beliefs in shaping hierarchies on teams. For example, in-degree centrality in the network analysis strand, which measures the number of incoming edges and can be interpreted as the degree to which team members perceive a person is contributing ideas particularly when considered relative to other team members, may be a preliminary indicator of influence on teams. I used data from fieldnotes and peer mentor journals to put findings from the quantitative strand in richer descriptive context by describing the team dynamics reflected in the quantitative strand.

Research Question Three

Related to the second question, research question three asks how Eurocentric epistemologies shape the four behavioral sequence, which I posited based on the sensitizing concepts I adopt from Status Characteristics Theory (i.e., action opportunities, performance outputs, performance evaluations, and influence). Here I drew on data from the quantitative strand, namely, the Group Communications Survey and Midterm Survey where students reported perceptions of their teammates' contributions and enactments during the design project. This data is directly related to the propositions discussed in Chapter 2. For example, if it is true that epistemological beliefs result in the marginalization of those students who do not adhere to Eurocentric epistemic values (i.e., scientific objectivity, value-neutrality, and the ideology of depoliticization), then one would expect to find that students whose beliefs align with the dominant epistemologies of the discipline would have their contributions recognized more often and their ideas enacted more often than those who did not.

However, the quantitative data represents summative evaluations of the team, and multiple alternative hypotheses exist that might inform how data in the quantitative strand is interpreted. For example, it may be the case that students are indeed contributing, but their contributions are not recognized. Second, it may be the case that students are not contributing, but this is due to processes of marginalization rather than from, for example, their disinterest in contributing to the team. To address these alternative hypotheses, I drew on descriptions of the team from peer mentors, student interviews, and my fieldnotes and reflective memos.

Research Question Four

Finally, the fourth research questions asks about the role of dominant epistemologies in processes of marginalization for students of color and women in engineering. Here I drew on descriptive analyses and the multilevel ERGM in the quantitative strand, which examined the role of race/ethnicity, gender, and process objectivity beliefs in perceptions of contributions and enactments. I then compared these results to qualitative data gathered from the individual interviews, observations, and peer mentor journals to help explain patterns I found I in the quantitative strand.

While I draw on descriptions provided by peer mentors in order to address the second, third, and fourth questions, I do not assume that peer mentors' responses to my journal prompts represent objective evaluations of the teams to which they were assigned. Indeed, I recognize that these descriptions are as value laden as my own descriptions and those provided by ENGR 100 students. Thus, I compared descriptions of the team dynamics as represented in interviews, journals, and survey data in order to provide a multifaceted description of each focal team.

Limitations

There are a number of limitations to this dissertation research that inform both the analysis and interpretation of findings herein. First, in-person interactions were terminated four weeks before the end of the semester due to the COVID-19 pandemic and the move to remote learning. This meant that the in-person laboratory component of the ENGR 100 project was terminated. However, students in this study continued to meet virtually for report-writing and communications tasks to complete the course. I continued to observe the focal teams as they completed their revised design project. As a result, I made changes to the data collection process, including moving the one-on-one interviews to a virtual setting and collecting peer mentor journals once instead of twice.

Second, in the qualitative strand, I could not observe all of each team's interactions. During the pilot study, I noticed teams delegated tasks such that participants occasionally worked in separate rooms (e.g., in the Fabrication Studio and Laboratory) simultaneously. As it was impossible to be in two places at once, this meant that I did not observe particular interactions. This, in fact, occurred with one of the focal teams, when they decided to separate in order to complete separate tasks. My priority was always to avoid impeding the team's work, and I reminded the team that my research should not shape the team's decisions on task delegations. This was a *seen danger* I understood as I entered the study, particularly as it related to *who* was delegated particular tasks that separated them from the team and *why*. To address this limitation, I coded for task delegation equity on the teams explicitly in my analysis process.

Third, my inability to observe all 12 teams in ENGR 100 is a limitation of this study. While I attempted to address this limitation by drawing on peer mentors for information about teams I did not observe directly, these peer mentors were not trained researchers and do not bring the same theoretical framework to their observations as I would. I attempted to address this limitation by orienting peer mentors' reflections towards particular behaviors and dynamics consistent with my theoretical framework. During the pilot study, I noticed several times (i.e., in written correspondence and in casual conversation) when peer mentors offered deep, meaningful reflection on their respective team's dynamics, offering support for inclusion of peer mentor journals and interviews.

Fourth, the scales measuring process objectivity, product objectivity, and depoliticization that I developed for this study, like other scales measuring epistemological beliefs I reviewed in Chapter 2, exhibited low internal consistency. This consistent finding might reflect an inherent limitation to studying epistemologies. For example, Louca and colleagues (2004) distinguished professed epistemologies—one's expressed views about knowledge that I suggest appear in responses to surveys—from enacted epistemologies—the views about knowledge that appear in one's behaviors. An additional distinction may be the one between how students respond in the abstract to questions about their beliefs (i.e., as on surveys) and what they do in educational and other team settings that reveal their beliefs. Survey responses may also reflect hypothetical scenarios students construct during the survey process, prior experiences students encountered in their engineering education careers, or other factors informing their responses in ways that might contribute to the low internal consistency exhibited in this and other studies.

Finally, an additional challenge in studying epistemologies lies in understanding what is not observed. That is, just as our epistemologies inform the types of questions we ask, they inform the questions we do not ask. Thus, my epistemology shaped information I gathered and relied on to answer my questions, the claims I made based on that information, and my defense of my claims. I attempted to address this reality by documenting specific interactions in which epistemic perspectives collided in the teams. Still, this presented me with somewhat of a methodological "Catch-22": I argue that the dominant epistemic culture is communicated and imposed on students in engineering education, but I entered the study hoping to see students engage and interact with epistemologies that do not align with the dominant perspective in engineering settings. How, then, can I distinguish between acquiescence with the dominant epistemological perspective of the discipline and true epistemic adherence and embodiment to the dominant culture of engineering? I attempted to do so by documenting those times when students seemed to align and diverge from their espoused epistemological perspective as measured by the ERB scale but my data result in questions about the measures' validity.

A number of scholars have noted the challenges in measuring epistemologies (e.g., Hofer, 2000; Buehl et al. 2002 as cited in DeBacker et al.). This might be because surveys measuring beliefs examine how individuals view engineering work (i.e., views espoused) rather than how their respective personal epistemologies show up in their behaviors in practice. This distinction is exacerbated in this study, where my conceptual framework posited that adherence to Eurocentric epistemologies is at times superficial in order to marginalize the work and ideas of students of color and women. As a result, it might be the case that women and students of color adhere to the Eurocentric view precisely because they do not have space to diverge from Eurocentrism while maintaining legitimacy as engineers in their teams.

To address this possibility, I documented times when students relied on sources of knowledge that did not adhere to the Eurocentric perspective—for example, when they appeared to rely on their own prior experiences, intuition, or guesswork—as well as how their ideas were received on their teams. I also asked students to expound on these moments in individual interviews and compared their responses to their espoused beliefs as measured by the Engineering-related Beliefs survey. My findings, however, cause me to problematize this reliance on the alignment between survey findings and students' behaviors in practice.

Chapter 4: Introducing the Focal Teams

I begin by providing an overview of the three focal teams consisting of 15 engineering students in brief team and individual profiles. In the team profiles, I provide a broad overview of (a) the demographic characteristics of the teams, and (b) each team's general approach to completing the ROV project over the course of the term, particularly as it relates to the role of dominant epistemologies over the course of the project.

In the individual profiles, I rely on several sources of data, including institutional data (i.e., demographic data), to describe students in the focal teams. I first describe study participants using data from a teambuilding exercise I observed at the start of the term. During the teambuilding exercise, students were asked to "re-introduce themselves" to their newly assigned team by describing their prior experiences and the engineering-related skills they would bring to their teams, as well as any skills they hoped to build over the course of the project. I document conversations during that exercise to reflect on how students' representations of their engineering selves might shape the types of action opportunities they took or were granted, as well as resulting performance opportunities, performance outputs, and influence in the focal teams.

I also use survey responses from participants' responses to Engineering-Related Beliefs (ERB) items collected at the beginning of the term. Recall that ERB scores were crafted around three manifestations of Eurocentric epistemologies guiding this study—process objectivity, product objectivity, and depoliticization. While both the quantitative and qualitative analyses focus particularly on students' beliefs about *process* objectivity, which described beliefs about how engineers should develop, communicate, and defend ideas in engineering, I present scores related to product objectivity and depoliticization to point to patterns in the scores (e.g., students with high process objectivity scores also generally had high product objectivity scores).

Finally, I describe each individual's role in their respective teams in the individual profiles around the four behavioral sequences posited by Status Characteristics Theory (i.e., action opportunities, performance outputs, performance evaluations, and influence). Since these roles were generally negotiated amongst the teams and were shaped by a variety of factors (e.g., one's prior experiences, patterns of influence, the skills students said they did or did not bring to the team), I describe the behaviors sequences in both the team and individual profiles.

Finally, in a member checking process, I asked participants to read their team and respective individual profiles to provide comments about their veracity, offer positive or negative feedback, or make additions. Following the students' review of their team and individual profiles, I made revisions reflecting our conversations in their respective interviews. Throughout this chapter, as well as the following findings chapters, I note where students expressed disagreements with my assessments and note where my understandings were clarified as a result of feedback from the students themselves.

Team Mobula

Team Mobula differed from other focal teams in this study along a number of factors central to the design process. Perhaps most notably, Team Mobula's final design differed vastly from the preliminary design concepts they presented during their Preliminary Design Review. This was due, in part, to the technical skills that members of Team Mobula possessed prior to the project. For example, whereas other teams were hampered by their inability to translate ideas using technical knowledge and tools such as SolidWorks®, multiple students in Team Mobula had strong skills in SolidWorks®, and were more prepared than other teams to present their ideas using technical tools as early as the Individual Design Proposal. Team Mobula, more than any other focal team in the study, relied on technical tools (e.g., SolidWorks®) and knowledge to communicate and defend ideas over the course of the project. Still, Team Mobula's insistence that their ideas be communicated using technical tools and terms resulted in an ironic delay in the building process—though they were first of the focal teams to successfully implement their ideas in SolidWorks®, for example, they were the last to earn approval to begin the building process. Moreover, Team Mobula struggled as their disparate design priorities for their team's ROV often resulted in challenges coming to consensus on key design decisions. Finally, Team Mobula was deeply affected by the COVID-19 cancellations, which resulted in a shift in task delegation strategies during the report writing that occurred near the end of the term.

Team Mobula's responses to ERB items at the start of the term can be found in Table 9 below, and a profile of each member follows. Like other teams in the study, Team Mobula was selected due, in part, to the racial/ethnic, gender, and epistemic diversity, as measured in the ERB items. Interestingly, though the guiding theoretical framework might suggest women and students of color might be least supportive of process and product objectivity, Addy, a Black woman on Team Mobula, had the highest score in each category.

Table 9. Standardized Mean Scores to ERB Items (Team Mobula)

Name	Race/Ethnicity	Sex	Process Objectivity	Product Objectivity A	Product Objectivity B	Depoliticization
Addy	Black	Female	1.44	1.64	0.42	-0.18
Chelsea	White	Female	-0.19	-0.26	-0.33	0.08
Kevin	Asian	Male	-0.69	0.07	-1.04	1.10
Matt	White	Male	0.70	0.17	0.03	-0.64
Max	Asian	Male	-0.08	-0.16	-0.33	0.23

Adaeze (Addy)

Adaeze (Addy) is a Black female, international student. She began the term by noting that she is a Naval Architecture and Marine Engineering major, the degree program perhaps most germane to the ROV project. Like other students in the focal teams who sought tasks consistent with their intended engineering majors (e.g., mechanical engineers pursuing and demonstrating SolidWorks® knowledge), over the course of the project, Addy took on tasks consistent with her NAME major, such as calculating and presenting hydrostatic and hydrodynamic stability analyses during the team's presentations. Though Addy often relied heavily on technical engineering knowledge to communicate and defend ideas to various audiences, her reliance on technical knowledge was not always successful in team meetings. Moreover, Team Mobula did not utilize ideas from Addy's Individual Design Proposal in their final design, in part, because critical design decisions were made at a team meeting in Addy's absence. During the team's building process, Addy worked alongside Max to begin building the team's ROV frame before the building portion of the project was terminated due to the COVID-19 pandemic.

During her interview, Addy wholly rejected the idea that race/ethnicity or gender had shaped her experience in Team Mobula, arguing that she felt that her team had treated her like everyone else. However, she also reflected on what she noted as strange instances, such as the fact that she noticed her team's contribution scores in Tandem had plummeted over the course of the project (i.e., suggesting some members did not believe everyone was contributing equally), and wondered why no one had communicated this with the entire team if it had been an issue. Interestingly, Addy's responses to ERB items at the beginning of the term suggested she was most likely to elevate technical engineering knowledge on this team. Indeed, her interactions in team meetings often featured heavy use of technical engineering knowledge, most notably in design disputes with Kevin.

Chelsea

Chelsea is a White female electrical engineering and computer science student. Chelsea's ideas were central to the team's design process, as her Individual Design Proposal became one of the three designs the team presented during their preliminary design review. Over the course of the project, Chelsea was heavily involved, alongside Matt, in building the team's control box, as well as producing technical communications materials (e.g., written reports). Still, though Chelsea featured heavily in the team's communications tasks, on several occasions she voiced frustration about the team's working process (e.g., when some of her work was modified without her knowledge prior to the Detailed Design Review presentation), as well as frustration with equity issues in task delegation over the course of the project. Finally, Chelsea's responses to ERB items at the beginning of the term suggested she was less likely to elevate technical engineering knowledge on this team, a position she reiterated on reflection in her interview following the design experience. Notably, Chelsea spoke at length about how gender shaped her experiences during the project, as well as her experiences in engineering broadly. On several occasions, she connected her experiences to larger issues of marginalization for women in engineering, suggesting that some of her interactions were particularly frustrating given her status as a woman in engineering.

Kevin

Kevin is an Asian male, undecided about his engineering major, but with expressed interests in mechanical engineering. Over the course of the project, Kevin took the lead on designing multiple features of the team's concepts. For example, during the Preliminary Design

Review, one of the two “innovations” (i.e., the two-part control box idea) was a product of Kevin’s Individual Design Proposal. Kevin also led the design and printing of the team’s custom part—thruster guards to address a critical design requirement. After the custom part drew heavy criticism during the team’s Detailed Design Review, an episode which is described in later sections, Kevin took the lead both in responding to the criticism and the team’s redesign of the custom part. Over the course of the project, I documented moments in which Team Mobula appeared to show deep deference to Kevin’s knowledge, with one student referring to the team’s general trust in Kevin’s work as “implicit” and that “you can tell that he (Kevin) knew what he was doing.”

Kevin’s responses to ERB items at the start of the term suggested he was least likely to elevate technical engineering knowledge during the design process than his teammates. However, throughout the design process, Kevin often presented ideas in terms of the technical knowledge in the course particularly during design debates with other teammates. Moreover, interview data suggested Kevin’s beliefs about knowledge transcended the specific context of engineering. For example, he once expressed confusion at the very premise of this research study, questioning me about how I intended to quantify my qualitative data so that it constituted real research.

Matthew (Matt)

Matthew (Matt) is a White male engineering student, who was undecided about his major at the time of the study, although he articulated interests in computer science and electrical engineering. Matt often took the lead on organizing the team’s activities, such as convening and organizing meetings, and he was particularly active during technical communication’s activities. Moreover, Matt, along with his teammate Kevin, demonstrated considerable technical skills using SolidWorks® at the start of the course. At the start of the project, Matt seemed keen on ensuring equal participation in the team. For example, during one particular lab session, Matt repeatedly reminded the team to “be sure everyone gets a chance to cut (PVC).” However, as the semester progressed, Matt became a more central figure in delegating tasks, particularly during the team’s technical communications work. For example, Matt’s influence over task delegation and action opportunities resulted in several instances in which Matt made decisions about the team’s work without the consent of his teammates. During the team’s building process Matt worked alongside Chelsea to build the team’s control box. Finally, Matt’s responses to ERB items, particularly those related to communicating and defending ideas, suggested he was more likely to elevate technical knowledge during the design process. However, during his interview, Matt articulated some epistemic tensions related to the workability of ERB items in practice during the project. For example, Matt noted that while a project in a first-year engineering course was “very low on the technical side of things,” he saw no alternative for ways to present ideas credibly. Still, he agreed with my assessment that he “did not present a lot of technical evidence” during design discussions over the course of the project.

Max

Max is an Asian male, undecided engineering student. During Team Mobula’s Preliminary Design Review, one of the two “innovations” was a product of Max’s Individual Design Proposal. According to Max’s responses to ERB items at the beginning of the term, he was less likely to elevate technical knowledge than other teammates in the team, a belief he reiterated at the end of the term during his interview. Yet I observed moments in which he appeared to rely on technical engineering knowledge to articulate ideas even when his grasp on the technical knowledge was tenuous. For example, when presenting his “fins” innovation during the PDR, Max admitted, “I don’t know much about the hydrodynamics or the physics behind it, but I do think the fin will help with stability.” During the building process, Max worked alongside Adaeze (Addy) to begin building the frame of the team’s ROV design before the build component of the project was terminated as the University went online due to the onset of the pandemic.

Team Surge

Unlike Team Mobula, Team Surge was consistently hampered by a disconnect between their ideas and the technical skills required to communicate and implement their ideas in the course. For example, early in the project, the team struggled to implement their ideas in SolidWorks®, and these struggles became a major limitation to the team’s design and building process. On several occasions, students resisted particular ideas, at least in part, because the team did not have confidence that they could implement in SolidWorks® or defend the ideas using the technical tools and knowledge they learned during the course. In general, Team Surge avoided the more technical course content except on occasions in which those aspects were required for the completion of assignments. Moreover, Team decisions around the role of technical tools, as well as the COVID-19 pandemic, resulted in Team Surge completing far fewer of the building tasks than the other focal teams.

Team Surge consisted of two White female students, two male students of color, and one White male student. While several students rejected the idea that race was a salient part of their experience, several interactions signaled that race was at least a conscious factor in how they viewed members of their team. For example, both male and female members of Team Surge related several disputes related to design decisions, task delegation, and communication to gender dynamics in engineering broadly and their team specifically. Finally, Team Surge’s responses to ERB items at the start of the term can be found in Table 10 below, and a profile of each member follows. Like other focal teams in the study, Team Surge was chosen, in part, due to racial/ethnic, gender, and epistemic diversity. Rehman's scores stood out amongst the group as the student elevating process and product objectivity more heavily than his teammates.

Table 10. Standardized Mean Scores to ERB Items (Team Surge)

Name	Race/Ethnicity	Sex	Process Objectivity	Product Objectivity A	Product Objectivity B	Depoliticization
Danish	Asian	Male	-0.34	-0.20	-0.31	0.22
Lauren	White	Female	-1.16	-0.80	-0.35	-0.36
Rehman	Asian	Male	1.21	1.31	0.36	-0.38
Ryan	White	Male	-0.30	-0.82	-0.34	0.36
Stephanie	White	Female	-0.08	0.05	0.01	-0.96

Danish

Danish is an Asian male student pursuing computer science. During a teambuilding exercise at the start of the project, Danish listed his coding experience as the primary skill he brought to Team Surge. Early in the term, Danish articulated that he would like to pursue tasks consistent with his coding background, asking the team to delegate tasks related to the team's control box to him. Moreover, early in the project, the team's initial design ideas were largely modifications of Danish's "trapezoid frame" design from his Individual Design Proposal. Though Danish's ERB scores suggested he was least likely to elevate technical knowledge, I observed his strategic use of technical knowledge to elevate particular ideas during team meetings. For example, during one design discussion, Danish became adamant that the Trapezoid Frame was the team's best choice for a design to pursue, often drawing on multiple sources of knowledge to defend the idea. When his argument failed to convince his teammates, he admitted that he purposefully and strategically changed his argument to use seemingly technical (but in my view, arbitrary) mathematical knowledge to convince the team the idea would work. Like other students who intended to work particularly on their team's control box, Danish's work was cut short following the cancellation of classes due to the COVID-19 pandemic.

Lauren

Lauren is a White female student pursuing computer science and cognitive science. During the teambuilding exercise at the start of the term, Lauren downplayed her prior skills and said she brought few technical engineering skills to Team Surge. Still, Lauren took an active role in the team's design process, often working with other team members at white boards to discuss and sketch the team's design ideas. Like the other members of Team Surge, and consistent with her ERB responses, Lauren was unlikely to communicate ideas in terms of the technical knowledge delivered in the course, choosing instead to rely on sketches and intuition to communicate ideas to the team. It was Lauren, for example, who sketched the team's final frame design, which was subsequently used to gain approval for the building process. During her interview, Lauren acknowledged that her relationship with her teammate, Stephanie, benefitted the two of them in their work on the team. Indeed, I noted several times in which Stephanie cleared the floor for Lauren to speak or communicate ideas to others on the team.

Rehman

Rehman is an Asian male computer engineering student who described himself as "half Indian" during his interview. During the teambuilding exercise, Rehman noted that he had prior experiences building ROVs during the team building exercises but acknowledged that he lacked the physics knowledge underlying ROV design, noting that he hoped to expand his knowledge of the physics behind underwater vehicles over the course of the project. Rehman's responses to the ERB items at the start of the term suggested he was most likely to elevate technical engineering knowledge during the design process. Unlike other members of the team, Rehman never claimed a particular component of the project as his central task, instead choosing to participate across the various tasks in the project. For example, on one particular day in lab, Rehman worked with Lauren and Stephanie on sketching the team's ROV frame, spoke with Danish about the early stages of constructing the team's control box, and discussed the team's CAD model with Ryan at the workbench.

Ryan

Ryan is a White male student majoring in naval architecture and marine engineering (NAME). Over the course of the project, Ryan served in a leadership role for Team Surge, often convening and organizing meetings, as well as leading design discussions. During the team building exercise, Ryan noted that, as a NAME major, there was a particular knowledge and skills base that he hoped to pursue over the course of the project and suggested he would take on tasks consistent with his major. At the start of the term, Ryan's responses to ERB items suggested he was less likely than other teammates to elevate the technical knowledge offered in the course. Over the course of the project, Ryan took the lead on technical aspects of the team's work, such as developing the team's CAD model and presenting Team Surge's hydrodynamic stability analyses in presentations and reports.

Ryan's role as de facto leader earned some pushback from teammates. During the project, Ryan engaged in several contentious arguments with teammates, particularly between Ryan and Stephanie, about opportunities to speak and be heard in team meetings. Upon reflection, Ryan discussed the role of gender in these arguments, noting the social and historical significance of the marginalization of women in engineering.

Stephanie

Stephanie is a White female undecided engineering student, though she expressed interest in both mechanical engineering and computer science. During the team-building exercise, and similar to Lauren, Stephanie joked that she brought "no engineering skills, but lots of enthusiasm" to the team. Stephanie articulated that there was a particular set of skills germane to her major (i.e., mechanical engineering), such as CAD modeling and building, that she hoped to develop over the course of the project. As a result, early in the project, Stephanie took the lead on modeling the team's initial design ideas in SolidWorks®, largely alone. Stephanie also frequently served as an arbitrator during discussions, often clearing the floor for other team members—Lauren in particular—to share ideas during more animated team discussions. Stephanie's early struggles with CAD modeling, as well as the inability of her teammates to offer support—featured heavily in the team's design process, and a number of design decisions were made particularly in light of the team's collective inability to implement ideas in SolidWorks®. Finally, Stephanie's responses to ERB items at the beginning of the term suggested she was less likely to elevate technical engineering knowledge during the design process, a position she reiterated in her post-experience interview. In particular, Stephanie articulated opposition to depoliticization, and expressed that her experiences as a woman in engineering left her deeply concerned with equity issues in team-based engineering work.

The Yachtsmen

The Yachtsmen were an all-White male team, which I selected, in part, due to the racial and gender homogeneity on the team. Moreover, the wide range of scores on their respective

ERB responses at the beginning of the term made The Yachtsmen an ideal focal team for the study. The team began the term struggling to achieve equal participation amongst all of its members; however, following a team-building exercise, during which students outlined their strengths and goals for the project, students began to seize on roles consistent with their stated strengths. Like Team Mobula, The Yachtsmen used technical tools, in particular CAD models, as a primary method for implementing, communicating, and modifying their design ideas over the course of the project. It was common, for example, for The Yachtsmen to first discuss design ideas using sketches and then discuss the feasibility of implementing those design ideas in SolidWorks®. Still, The Yachtsmen were keen to relate their skills and ideas to their prior experiences (e.g., experiences growing up, experiences with technical engineering skills such as coding and using CAD software). The Yachtsmen quickly made simplicity a key design priority, hoping to build their ROV quickly to prioritize testing, data collection, and adjustments during the design process. Thus, unlike the other focal teams, The Yachtsmen made few major changes over the course of the design process between their Preliminary Design Review and the start of their building phase. As a result, The Yachtsmen were the first and only team to complete the initial building and testing of their design.

Finally, The Yachtsmen's responses to ERB items at the start of the term can be found in Table 11 below, and a profile of each member follows. The Yachtsmen were the only focal team in which the majority of the standardized process and product objectivity scores were positive. Still, the ways in which the Yachtsmen described the role of technical engineering knowledge, which I describe in the next chapters, varied widely.

Table 11. Standardized Mean Scores to ERB Items (The Yachtsmen)

Name	Race/Ethnicity	Sex	Process Objectivity	Product Objectivity A	Product Objectivity B	Depoliticization
Cam	White	Male	0.98	0.11	0.73	0.23
John	White	Male	0.39	-0.47	-0.33	-0.33
Kyle	White	Male	0.52	0.32	-0.33	-0.52
Paul	White	Male	-0.07	0.72	-0.34	1.98
Seth	White	Male	-0.54	-1.75	-1.04	-0.94

Cameron (Cam)

Cameron (Cam) is a White male student who indicated he is majoring in mechanical engineering. At the start of the project, Cam listed his prior experience with computer-aided design (CAD) as a core skill that he brought to the team. Early in the project he did not participate heavily in design discussions and debates as the team negotiated preliminary design ideas due, in part, to his discomfort interacting with others. Yet his CAD skills resulted in his teammates' decision to delegate the CAD model to him in order to facilitate his involvement. As a result, over the course of the project, Cam took on the responsibility of implementing the team's evolving design ideas, including the changes in SolidWorks®. This meant that Cam served as a gatekeeper, determining the ideas that moved forward, as well as how particular ideas were represented in the team's documentation. As Cam's CAD skills became more relevant to the team's work, he became more involved in team meetings and discussions. Finally, Cam's ERB score indicated a likelihood to elevate technical knowledge and skills in his design work, which was consistent with approach to problem solving over the course of the term. However, following the project, Cam acknowledged that his perspectives had evolved; he acknowledged the “human factor” in engineering work and argued “you can’t just rely on numbers and observation to support your claims.”

John

John is a White male engineering student pursuing computer science. During the teambuilding exercise, John listed mathematics and computer programming as the primary strengths he brought to The Yachtsmen. Over the course of the project, he took the lead on developing the team’s custom part, once drawing criticism from the team’s peer mentor for referring to the custom part as “my little project” (i.e., rather than a team effort). John made a habit of translating his ideas into the technical terms and knowledge, often suggesting the team should do the same. Indeed, during a team meeting in which The Yachtsmen discussed ways to improve their design innovation score for the competition, John who suggested the team could not possibly be effective without pursuing mathematical and scientific support for their ideas, arguing, “We’re gonna have to do some math, boys, or else we don’t know what the hell we’re doing!”

During the team’s building phase, John worked alongside Paul to address issues that arose regarding thrusters and the team’s custom shrouds. John’s role in presenting and defending the team’s ROV design became particularly prominent during the Team’s Detailed Design Review, during which John had the task of defending the team’s custom part shortly after a similar custom part had been heavily criticized. Still, John drew on research and technical knowledge to successfully defend the idea to the class.

Kyle

Kyle is a White male engineering student majoring in biomedical engineering. Over the course of the project, Kyle took on a de facto leadership role on the team, often convening and organizing team meetings and ideas throughout the project. During a teambuilding exercise at the start of the project, Kyle described his strengths in terms of his experiences growing up, adding that he's "good at putting stuff together." Kyle's leadership on the team was particularly felt during early design discussions, where he often took the lead by drawing and sketching design ideas, relaying information and decisions to the team, and facilitating ideas from other team members. Kyle was also instrumental in leading and coordinating the building process. Finally, Kyle's responses to ERB items at the start of the term suggested he was likely to elevate technical sources of knowledge during the design process. However, at times he voiced frustration with the team's reliance on technical terms during discussions, telling the team, "See, you guys can just talk through this stuff. I actually have to see it."

Paul

Paul is a White male student majoring in computer science. Paul served as a "jack of all trades" for The Yachtsmen, often participating at least peripherally in various tasks during the project. Hailing from the self-titled "Hickerbilly, Michigan," Paul described his engineering competencies in terms of the skills he'd learned growing up in rural Michigan. "I grew up on a farm," he told the team during the team-building exercise, "so I'm good at building stuff." During his interview, Paul joked about the central role of his blue-collar background in his approach to engineering, particularly during building tasks. For example, during a laboratory session in which The Yachtsmen assembled their ROV quickly and without care, Paul joked, "That's some redneck work there!" Paul also related his background to his working relationships with his teammates, suggesting he got along with Kyle because they shared similar blue-collar backgrounds during which they had similar experiences and developed similar engineering-related skills.

Unlike other members of the team, Paul's design activities were not limited to the skills he believed he brought to the team. For example, early in the design process, I often observed Paul sketching design ideas on paper or white boards and leading design discussions along with Kyle. Paul's ERB score suggested he was less likely to elevate technical engineering knowledge, and over the course of the project, he was unlikely to rely on the technical knowledge to communicate ideas, relying instead on analogies from his background, cultural experiences, and sketches to describe design ideas. Paul reflected on his behaviors on his team, articulating an epistemic tension between his internal approach to solving engineering problems with what he understood to be the requisite methods for presenting and defending ideas in engineering.

Seth

Seth is a White male student pursuing computer science. At the start of the term, Seth listed his coding skills as the primary skill he brought to The Yachtsmen, though he later acknowledged he had overstated his coding skills due to his perception that others brought tangible engineering skills, as well as in anticipation that task delegation would reflect their respective stated skills. Over the course of the project, Seth most often participated in team discussions by asking questions, eliciting feedback from teammates, and working to ensure full participation on the team. In marked contrast to other team members, Seth was often concerned with the feedback and participation of others on the team. For example, Seth once expressed concern that the team was due to make decisions about an important aspect of their Preliminary Design Review, the Decision Matrix, in Cameron's absence, prompting the team to discuss ways to get either Cameron's input or approval before submission. While the team was able to build their full ROV, the project was cancelled prior to the team engaging with their control box, the technical building portion of the project for which Seth's coding skills would likely have been most relevant. Still, Seth played a role in the building process, working with Kyle and Cameron to complete the ROV frame. Finally, Seth's responses to ERB items at the beginning of the term suggested he was least likely to elevate technical knowledge in the course on the team, a position he reiterated in his interview.

Summary

The purpose of these profiles was both to introduce the reader to the three focal teams and their members. In the three chapters to come, I combine data from the ERB survey responses, my observations, interviews, and peer mentor journals to identify key themes that address my research questions. Two of these research questions focus on how students' epistemological beliefs about engineering influence status hierarchies and behavioral sequences in student design teams. While I did not anticipate students would articulate the role of Eurocentric epistemologies in status hierarchies directly, the information provided in the profiles serves as a preview to my discussions in later chapters. The recurring role that proficiency with technical tools played in garnering influence on teams also points to the normative supremacy of Eurocentric epistemologies in teams. In the coming chapters, I also explore the role of dominant epistemologies in marginalizing students of color and women in engineering. Across the teams and individuals, I draw on students' discussions of gender dynamics in their respective teams, including how gender shaped the ideas that were elevated, whose ideas were heard or discarded, and how gender shaped task delegation and influence on each team.

Chapter 5: Introduction to the Design Process

Descriptions of the engineering design processed are often presented as iterative, staged-based models that define the overarching processes and activities that engineering design entails. For example, Pahl, Beitz, Feldhusen, and Grote (2007) describes design as an iterative process that includes at least four broad stages: (a) Task Clarification, during which designers identify and clarify the general and task-specific requirements and constraints of the design problem, (b) Conceptual Design, which entails the laying out the basic solution principles of the design, (c) Embodiment Design, in which designers clarify basic solution principles based on constraints and requirements, and (d) Detail Design, which completes the embodiment design phase by finalizing the "shapes, forms, dimensions and surface properties of all individual components, the definitive selection of materials, and a final scrutiny of the production methods, operating procedures, and costs" (Pahl, Beitz, Feldhusen, & Grote 2007, p. 436).[8]

The ENGR 100 course structure followed a similar structure. Indeed, the instructors in jokingly referred to the design process as a "Jeremy Bearimy," a reference to the NBC sitcom *The Good Place,* suggesting the design process is not prescriptive and linear. Rather, like the "Jeremy Bearimy" image, the design process iterative, and the instructors anticipated students might return to various aspects of the project as they clarified their ideas. The Task Clarification phase of the project was largely taken on in lecture-style class meetings at the beginning of the course and prior to students' being assigned their project teams. The Conceptual Design phase

[8] There are many models of the engineering design process. I do not mean to suggest that the ENGR 100 course followed Pahl and colleagues' model neatly. I have chosen this model because it provides broad, overarching categories around which to organize chronological events in this study.

began at the individual level through the Individual Design Proposal and included team-based negotiations of ideas after students were placed in their project teams. Finally, the Embodiment and Detail Design phases were largely carried out in students' respective design teams.

Over the next two chapters, I construct parallel narratives about Team Mobula, Team Surge, and The Yachtsmen in order to use the common experiences across the teams to compare and contrast each team's approach to the ENGR 100 ROV project. I begin in this chapter by describing how students discussed their process of developing their individual concepts prior to entering their teams (i.e., the Individual Design Proposal) and the role dominant epistemologies played at the individual level. At both the individual and team levels, each student and team faced the same key design decisions, participated in the same milestone experiences (e.g., class presentations and assignments), and engaged in similar team processes (e.g., task delegation, performance evaluations) over the course of the project. In this chapter I describe the key design decisions and how students developed ideas at the individual level prior to entering their final design teams. These descriptions serve to show how the dominant epistemic culture of the discipline appeared throughout the design process even before students were negotiating ideas in teams.

Key Design Decisions

At the individual and team-level, students developed their initial ROV concepts around a set of key design decisions that included (a) the shape and structure of the ROV frame, (b) the degrees of freedom in which their ROV would be capable of traveling, (c) the placement of their four allotted thrusters, (d) the design and construction of a control box for driving their ROV, and (e) the design of a course-required custom part. As all of these decisions are interrelated, with one informing the others. Students, at both the individual and team levels, did not proceed in a particular order and no single decision was necessarily prioritized over the others.

For example, one major decision was the frame of the ROV, which would hold other components of the team's design (e.g., the payload, thrusters, camera). The frame is a key design decision as it informs the other design decisions the students and teams must make. Second, since teams were limited to four thrusters, students had to decide the degrees of freedom they would pursue in their respective designs. Degrees of freedom refer to the independent directions in which the ROV could travel. Students were to determine how they would organize their limited thrusters in order to achieve the degrees of freedom (i.e., surge, heave, yaw, sway, roll, or pitch) they believed were important for accomplishing their design goals. Third, and related to the choice of degrees of freedom, students were required to make design decisions around thruster placement. Fourth, students were required to design and implement a control box used to drive their ROV while it was underwater. Finally, the instructors in the course required each team to design a custom part—some piece of the design that was not included in the materials provided by the instructors. Each team needed to indicate the purpose of their custom part and include in their final report some evidence that it accomplished its goal. The world of affordances that students were allowed to pursue regarding their custom part was broad. Some students designed and 3-D printed custom parts. Others developed custom code for their control boxes. Importantly, most often, students designed custom parts to address specific design issues they encountered as they developed their team's concepts.

Individual Ideation

In addition to the key design decisions, the course also proceeded based on a set of key course milestones and deliverables (i.e., assignments) designed to facilitate student and team design thinking and progress over the course of the project. In this chapter, I begin with the first course milestone—the Individual Design Proposal. Specifically, I discuss the role of Eurocentric epistemologies in individual ideation. In the next chapter, I discuss team-based design processes (e.g., negotiating ideas and selecting concepts to pursue), as well as students' reflections at the end of the course. I also describe the role of dominant epistemologies in team-based design processes by discussing my observations around the key design dilemmas and decisions that shaped the team's interactions.

In the first course milestone, students were assigned an *Individual Design Proposal* (IDP) prior to joining their project teams. Students were told that the purpose of the IDP was to ensure that everyone had given the project at least some thought before entering their teams. The Technical Communications instructor, Heather, explicitly told students that the purpose of the IDP was to avoid having a team follow the ideas of one influential individual. Unintentionally, the ENGR instructors anticipated the overall premise of Status Characteristics Theory (SCT), which is that newly formed groups quickly develop internal power orders, and they hoped to subvert the tendency for teams to organize around individual influence and power in favor of collective thinking.

Prior to students' submissions of their IDPs, the class participated in a series of lectures about the project during which they discussed the project goals via a fictional request for proposals (RFP). As student began to develop their IDPs Heather facilitated an activity titled "Where Do Ideas Come From?" During the activity, Heather acknowledged that, historically (i.e., in previous iterations of the course) most students entered the course with little to no knowledge about ROVs. As a result, she asked students to reflect on how they might generate ideas for their ROVs.

Heather began by juxtaposing the "'heroic theory' of creativity/ideation" with multiple discovery. Heather made it clear that she opposed the "heroic theory" wherein students allowed "one genius" on the team to "run the team," and indicated that it was "much better for students to come together and negotiate ideas." As I listened to Heather's advice to the class, I was reminded of Dym and colleagues' (2005) reference to the "eureka moment," as well as Kant and Kerr's (2017) "mythical engineering…typically, a man," and wondered who on these teams might be most likely to be perceived as the "genius running the team." Heather concluded with definitive advice—"Want to build something great? Build off of, recombine other ideas" making explicit her preference and expectations for full participation in the teams.

Students were then charged with developing their IDPs. Since the IDPs were completed individually prior to team assignments, they occurred before students agreed to participate in this study and outside of my view. However, I returned to the IDPs during interviews with each of the 15 members of the focal teams to discuss their process of developing their IDPs. During interviews, I focused particularly on how students developed and described their priorities during the individual ideation process, as well as how students described the sources of their ideas.

Non-Eurocentric Epistemologies: The role of prior experiences

I begin by discussing those students on the focal teams who appeared refer to alternative sources of knowledge as they developed their individual concepts. During their one-on-one interviews, several students discussed their prior experiences, or lack thereof, when describing how they made decisions around their individual design proposals. For example, two students spoke about their understanding of the design process and how this led them to prioritizing simplicity over complexity in their respective individual designs. Rather than focus on the technical details of the project, these two students instead described their priorities in terms of what they had learned from prior design experiences. For example, Kevin (Team Mobula), described his prior robotics experiences and how those experiences led him to choosing simplicity over "anything fancy" in his IDP:

> I have experience in high school on a robotics team, so I was looking at the timeline and I realized that there wasn't going to be enough time to do anything fancy, so for the individual design proposal I just went for a very simplistic [sic] design that had the degrees of freedom that we needed, and I was going to focus mostly on the driving aspect because in high school I would build something that's really cool and conceptually worked really well. Because I finished it a day or two before competitions, I wouldn't get any driver practice in, and so there'd be unforeseen problems and just lack of experience that would cause us to lose matches, so I tried to focus on giving us a week or two at least to just practice driving because in water you also have to deal with extra dimensions so it's even harder than on land. So, I was just focused on that.

Kevin's drawing on his prior experiences rather than explicit representations of the technical details and implications of his decisions was uncharacteristic for him across the project, with implications for how he approached the design process once he joined Team Mobula. As I noted in the prior chapter, Kevin's interactions on his team often centered explicit discussions of technical knowledge related to his ideas and decisions, which won him the trust of his teammates. Still, Kevin's focus on his prior experiences to make key design decisions around degrees of freedom and other details of his individual design rather than technical defense of his ideas was different from his teammates, who openly spoke about their concerns about supporting their ideas with research, math and physics knowledge, or other sources of knowledge.

Similarly, Rehman (Team Surge) shared how his prior experiences building ROVs had shaped his approach to the individual design process. Like Kevin, Rehman decided to prioritize simplicity over complexity, referencing his prior experiences to describe his decision:

> I actually found that [prior ROV design experience] was really helpful…especially when we got to the individual design part. Most of my stuff I had already tested out and knew it was going to work because I had already built this…

Rehman continued reflecting on how his prior experiences shaped the ideas he decided to pursue, leading him to choose a more simplistic approach and guiding his decisions around key design decisions, such as thruster placement and frame design:

> You can do a lot with a box shape and it won't really impact... It's very structurally sound and it won't impact your movements that much, versus a radical design. Overall, it's just not worth, especially using just PVC pipe, it's not worth the radical design compared to just the box because the box works fine. I used the box and then I put the motors on the outside. My surge motors were on the outside with little protective... That was my custom part were these little protective things on the outside because you don't want them to get hit but having the motors on the outside was really important, I thought, because... Especially with the ones I did in high school, the smaller ones, when they're in the inside, you really... You could only turn by going forward in one direction and back in the other. That was it. It was slow turning and stuff like that, so I wanted to be able to turn, so I put them on the outside, because I knew that was going to be helpful.

Kevin and Rehman's reflection on the role of their prior experiences in their individual design proposals demonstrate that students do not enter team-based design experiences as "blank slates" waiting to absorb knowledge from instructors. Instead, Kevin and Rehman's prior experiences shaped their thinking about the project even before instructors imparted project guidelines and constraints. In contrast, other students acknowledged they lacked prior engineering experiences and knowledge upon entering the course, raising the question of where students turned when they felt they lacked the experience and knowledge to make decisions during the design process. On this, students appeared to rely on two factors shaped students' approach to the design process—intuition and the normative supremacy of Eurocentric epistemologies.

Math and Physics Intuition as a Source of Engineering Ideas

Other students in the study spoke about their relative inexperience and lack of knowledge about ROVs and the sources of knowledge they turned to in order to generate ideas. This lack of experience and knowledge led students to discuss a resulting lack of confidence in their ideas, as well as how they worked through their lack of confidence to generate and present their individual design proposals. For example, Paul (The Yachtsmen) discussed his belief that he lacked creativity and struggled to develop innovative ideas. As a result, Paul pursued a simple design:

> Honestly, with me, personally, I am not a creative person, whatsoever. It's so hard for me to think of ideas on my own, unless I'm with someone bouncing off different ideas. But if I just sit down and try and come up with a new invention or innovation, it was very difficult for me, because I had sat down and thought about these things a lot. So, for my individualization [sic], I really just took a basic, simple design from lecture, and then just made it balanced…So to me, it didn't need to be fancy. It just needed to get the job done.

Still, Paul understood that his ideas required adequate defense, and turned to intuition to describe the source of his ideas. When describing the sources of his ideas, Paul noted that some of his concepts were "mathematically intuitive," and that after explanations from instructors, it simply "makes sense that it made everything work."

Similarly, Ryan (Team Surge) discussed drawing on commercially available ROVs and intuition to develop his individual design proposal due to his lack of experience and knowledge:

> Well, I guess I feel like for a student that doesn't have a ton of experience, it's all just stuff that you might just see in passing. I feel like everybody's seen like a picture of an ROV in some documentary movie just in passing, even if they haven't really paid attention to it or just like any... I think that all the ideas come from just the back of the mind after you happened to just see something early in your life and don't even notice it. I think it's just a lot of chance, the coming up with the ideas.

When discussing how he presented those ideas to his team, Ryan remarked that he tried to "make inferences about how things would work" based on the "very little bit" of knowledge he had about ROVs and acknowledged that he drew on those inferences even when he "didn't have the technical knowledge to back up" ideas. Danish (Team Surge) similarly remarked that some of his design decisions were "based on a whim" that the decision might improve his design, suggesting he relied on intuition to make some design decisions.

Other students similarly described their ideas in terms of mathematics or physics intuition. When I observed Max (Team Mobula) respond to questions about his custom part, a pair of "fins" atop the ROV frame, he remarked "I don't know much about the hydrodynamics or physics behind it, but I do think the fin will help with stability." When I returned to this moment during his interview, Max referred to the fins as "a completely random idea" that "just came to me." He later acknowledged that he "didn't put a lot of reasoning behind it."

In this study, I documented moments during which students appeared to rely on guesswork or intuition. Though I distinguished *guesswork* from *intuition*, this distinction was at times difficult to ascertain in practice. Lieberman, Jarcho, and Satpute (2004) distinguish evidence-based self-knowledge, which "results from an evidentiary process of retrieving and evaluating autobiographical information," from intuition-based self-knowledge, which results from "implicit, tacit, or automatic self-processes that operate without effort, intention, or awareness…based on accumulated experiences without the explicit retrieval and evaluation of autobiographical evidence" (p. 422). However, throughout these narratives I suggest neither guesswork nor intuition entail explicit representations of technical engineering knowledge.

Intuition, for example, may entail mathematical and scientific components (e.g., physics intuition), but the absence of explicit representations of physics knowledge does not, in my view, constitute adherence to Eurocentric epistemologies, particularly in team settings. That some students felt the need to clarify and justify concepts using explicit representations of mathematic and scientific knowledge (e.g., calculations or research) while others forged ahead, comfortable relying on guesswork and intuition, suggests that the normative supremacy of Eurocentric epistemologies—the sources of knowledge and justification perceived to be legitimate—shaped assumptions about when such justifications are necessary and what role those justifications have in elevating particular ideas.

The Eurocentric perspective establishes math and science as the best method for knowing since math and science are viewed as objective, value-neutral, and impartial (Ladson-Billings, 2000). Moreover, The Eurocentric perspective established mathematic and scientific *reasoning* are the best ways of knowing (see *process objectivity*, Grincheva, 2013). Intuition, by its very definition, implies a lack of explicit, external mathematic and scientific reasoning. Indeed, each of the students who referred to the use of intuition did so in the context of explaining their lack of experience and knowledge. However, I wish to assert my view that intuition is a valid form and source of knowledge, particularly in teaching and learning contexts. Instead, I juxtapose this section with the next section on the role the normative supremacy of Eurocentric epistemologies in shaping the ideas some students discarded or hesitated to pursue. In particular, I discuss students' desire to represent their ideas with explicit support (i.e., research, external reasoning), and how this desire shaped the ideas students developed at the individual level.

Eurocentric Epistemologies and Individual Design Processes

The purpose of this chapter is to understand how ideas about generating, presenting, and defending ideas used by individuals might appear in team-based design processes. Thus, I describe but do not draw conclusions about individual epistemic values based on students' approaches to the IDP. Students in the study spoke about difficulties developing ideas in light of their lack of experience and knowledge. In particular, students spoke about being hampered, in part, for their inability to support their ideas with adequate *reasoning*—mathematics, science, and research support for their ideas. For example, Stephanie (Team Surge) described how she struggled to develop her IDP due to her inability to support her ideas with research to feel confident:

> For my individual design, honestly, I was really struggling with it when I made it. Just because it came on really early in the process and I didn't know anything. Me as a person, I have a hard time getting behind an idea when I haven't done a ton of research and don't feel confident. Being like, "I feel like we should do this for this reason."

Similarly, when reflecting on the process of developing her individual design proposal, Chelsea (Team Mobula) said, “I didn’t really understand exactly what I was doing,” and as a result, she was most focused on the thruster placement since it was the thing she understood most. When I asked about her confidence in her ideas, she remarked that she “wasn’t super confident” because she “didn’t really have any knowledge about ROVs.” Like Stephanie, Chelsea described feeling uneasy about particular ideas due to her inability to support those ideas with adequate reasoning.

To drive their points home, Stephanie and Chelsea both articulated an aversion to *guesswork* and *intuition*. Importantly, and germane to the next sections, both Stephanie and Chelsea noted that were reluctant to pursue particular ideas since they did not feel they had the technical knowledge to support and adequately defend their ideas. Chelsea, for example, noted that she was open to other ideas over her own because she felt as though her ideas were based on guesswork:

> Yeah. I wasn't super confident. I mean, none of us were because we didn't really have any knowledge about ROVs at all. All my ideas were just like, "I think this would work." I was confident-ish about my thruster placement. I thought it would work, but I wasn't necessarily sure that it would be the best idea. It’s like if anyone else has another idea, I'm definitely open to it because it definitely could be better.

Chelsea’s hesitance to pursue or advocate for ideas for which she believed she had little knowledge is a pattern I documented during the team process as well, which I discuss in the next chapter. Still, that some students were open about their use of intuition, while others were uneasy about their inability to provide reasoning—research or knowledge about ROVs—was noteworthy. Ironically, it appeared that the students who referred to their own lack of experiences and knowledge were most concerned with adhering to normative Eurocentric epistemologies by supporting their ideas with math, science, and research even during the individual design phase.

Eurocentric Epistemologies and Deference to Authorities

Another way in which the normative supremacy of Eurocentric epistemologies appeared during the individual design process was in explicit deference to authority—instructors, prior ENGR 100, students, and ROV designers via commercially available ROVs. As students began to recognize that they lacked the technical knowledge to reason through the development of their IDPs, they reported turning to other sources of knowledge to justify their design decisions. For example, Seth (The Yachtsmen) discussed how he determined his thruster placement by looking at commercially available ROVs:

> I sort of just looked up a bunch of ROVs that are commercially available. More like recreational ROVs that just have cameras on them, and I sort of used those to figure out what the best thruster placement was and why they put thrusters where they did. Then based off of that I sort of just put everything together to generally be hydrostatically stable, I guess.

Seth's teammate, Kyle, similarly drew ideas from commercially available ROVs to make key design decisions. Importantly, both Seth and Kyle described how they made decisions around thruster placement based on what they saw in the commercially available ROVs they viewed:

> When I first signed up for the class, I thought it was kind of a cool concept, being able to do that [build ROVs]. So, I had some ideas just coming into the class of what I wanted to do, and then I watched a lot of YouTube videos about just commercially available things like that and kind of just took ideas from those designs and kind of put them together as far as my overall thruster placement. And then I kind of just morphed my frame and moved components around so that they would kind of fit into that design.

Other "authorities" students turned to in the course included the work of prior students, as published by the course instructors in public forums such as Amy's (i.e., the course technical instructor) twitter page. For example, Addy (Team Mobula) described turning to "real-world ROVs," as well as the ROVs prior students had developed, to make decisions about key design decisions in her individual design proposal:

> I obviously went online, looked at the Amy's twitter page and I generally looked for like things that ROVs had in common, like those that were previously built by like Michigan students, but then like real world, ROVs, the basic function, what they needed to do. Yeah, I just gathered ideas from all of that.

Deference to authorities (e.g., instructors, peer mentors, commercially available ROVs) when justifying ideas was a recurring theme during both individual and team-based design processes.

As a result, as students entered their teams, I became cognizant of the use of guesswork and intuition, methods of reasoning through the key design issues, and other ways that students presented and defending their ideas to their teams. Though this study is centrally focused on the role of Eurocentric epistemologies in team-based design settings, I chose to describe the process of developing individual design proposal since a number of the factors that informed students' approaches at the individual level might also appear at the team level. I wondered, for example, how individual aversion to guesswork might shape discussions after students entered their teams. In the next chapter, I discuss the early stages of each team's design process, including how students presented and negotiated individual ideas to develop the 2-3 designs they presented during the Preliminary Design Review.

Summary

In this chapter, I focused on the ways that Eurocentric epistemologies appeared to shape students' design processes at the individual level as a first step in understanding how students' epistemologies at the individual level shape the design process at the team level. I discussed how, while some students appeared burdened by the need to provide adequate support for their ideas in the form of math and scientific knowledge, suitable reasoning, and ideas from authorities, others appeared comfortable and confident proceeding based on their prior experiences, guesswork, or intuition. In the next chapter, I discuss manifestations of Eurocentric epistemologies that appeared at the team level, including the ways Eurocentric epistemologies appeared to inform students' work on their teams, team interactions, and collective decisions during the team-based design process. As I show in the next chapter, the ways that Eurocentric epistemologies appeared to shape students' assessments of their own ideas while developing their Individual Design Proposals also shaped their interactions in their teams, as well as the decisions teams made during the design process.

Chapter 6: Manifestations of Eurocentric Epistemologies in Team-Based Design Settings

In the last chapter, I described how dominant Eurocentric epistemologies appeared to shape students' approaches to the design processes at the individual level. This included how students generated their preliminary design ideas, as well as how they elected to pursue or avoid particular ideas while developing their Individual Design Proposals. In this chapter, I use the data from my observations and interviews to describe how teams negotiated their individual ideas into a set of concepts for their team-based Preliminary Design Review presentations, as well as how teams narrowed down their ideas for their Detailed Design Review presentations and, ultimately, for their final ROV design.

This chapter is organized around six manifestations of Eurocentric epistemologies I observed in the three focal teams. For each manifestation, I describe the ways that normative Eurocentric epistemologies appeared in the form of explicit, observable behaviors by members of the three focal teams and how these appeared to shape individual and team actions and interactions. The identification and description of these manifestations represents a major contribution of this research because while epistemologies are generally studied as individual traits or characteristics of the individual mind, I show how these epistemologies are socially situated in teams and consequential for both individuals and for team design efforts.

In designing this study, I stated several propositions based on my reading of prior theory and research (see Chapter 2). Proposition 1 stated that engineering students whose epistemological perspectives align with dominant Eurocentric epistemic values will become high-status members who would take, or be granted, more action opportunities during the design process. In addition, Proposition 2 stated that students who adhere to scientific objectivity, value-neutrality, and the ideology of depoliticization in engineering will earn higher status on their respective design teams, which will result in more action opportunities and performance outputs. Proposition 3 stated that engineering students who adhere to the objectivity, value-neutrality, and the ideology of depoliticization in engineering will receive more positive performance evaluations in team settings, and Proposition 4 stated that students who adhered to the normative supremacy of Eurocentric epistemologies would wield greater influence in their teams. In this study, I suggest status and influence in engineering teams is manifested in the ideas teams consider, pursue, and discard during the project. Finally, because I assumed that characteristics such as race/ethnicity and gender, and by extension racism and sexism, would shape team-based design processes, Proposition 5 stated that characteristics, such as race and gender, will result in varying patterns related to the degree to which adherence to scientific objectivity, value-neutrality, and the ideology of depoliticization result in higher status on design teams.

In each section in which I describe a manifestation, I illustrate the manifestation by drawing on episodes across the focal teams. These episodes show how a specific manifestation appeared to shape team-based design processes by influencing the ideas that the focal teams chose to pursue. The episodes also reveal how different ideas were presented by individuals to their respective teams, and how these various ideas were elevated, selected, or discarded, as well as how different tasks were taken or delegated. Second, I discuss how the evidence in each manifestation relates to the propositions I stated in Chapter 2.

Overall, while the propositions point to three values (i.e., scientific objectivity, depoliticization, value-neutrality), I found the most evidence linking students' understanding of scientific objectivity to the sensitizing concepts included in the propositions. I suggest the absence of students' attention to depoliticization and value-neutrality likely reflects the nature of this first-year course and design task. More senior courses, where students engage with industry partners, or more complex real-world projects, might have evoked more discussions of depoliticization and the role of personal values in engineering. Still, I argue that the normative supremacy of Eurocentric epistemologies, most notably in the form of scientific objectivity, played a large role in both individual and team design processes. I conclude this chapter with a discussion of the role of Eurocentric epistemologies in students' perceptions of team cohesion.

Manifestation 1: The Need for Explicit Support

In the previous chapter, I described the ways that some students felt the need to offer explicit support—research, equations, reasoning—for their ideas as they developed their individual design proposals. As students described the process by which their teams selected ideas for the Preliminary Design Review, as well as the process by which their teams narrowed down their ideas for the Detailed Design Review, some students' hesitance to pursue ideas when they felt they did not have explicit support appeared to shape design discussions at the team level.

Each of the focal teams chose a different approach to developing their PDR. Recall that, for the PDR teams were to present two to three concepts under consideration by drawing on their Individual Design Proposals (IDPs). In preparation for their Preliminary Design Review, Team Mobula did not choose the entirety of any one individual design proposal. Instead, Team Mobula chose components from several of the team members' IDPs. During their individual interviews, some students had acknowledged that concerns about the inability to adequately justify ideas made them reluctant to pursue those ideas in their teams. Chelsea, for example, acknowledged that, without the ability to support her ideas, she had deferred to other team members about some key design decisions:

> Yeah. I wasn't super confident. I mean, none of us were because we didn't really have any knowledge about ROVs and all. All my ideas were just like, "I think this would work." I was confident-ish about my thruster placement. I thought it would work, but I wasn't necessarily sure that it would be the best idea. It’s like if anyone else has another idea, I'm definitely open to it because it definitely could be better.

Similarly, Max discussed not advocating for some ideas, in part, because he lacked suitable reasoning for them. For example, when describing his “angled thruster” ideas he noted:

> Honestly, I didn't really think that far. What kind of happened was when our group got together to discuss each of our individual design proposals, I kind of looked back at the angled thrusters idea, and I was like, "This is going to be pretty hard to implement," simply because mounting it would be pretty painful. They would have to be the exact same angle on each side. And so looking back at it now, it's not as viable of an option. I don't know. I didn't really put a lot of reasoning behind it, I guess.

When he described his proposed “fins” innovation, Max similarly described not advocating for the idea because he was not certain he had appropriate reasoning for the idea:

> I think at first they [Team Mobula] thought it [the “fins” ideas] was kind of cool. And our running joke was that it was style point, because Team Mobula, fins. It just goes hand in hand. But to be honest, the fins were kind of similar to the angled thrusters in that I just kind of thought of it. I didn't really have a lot of reasoning behind it. My reasoning for it was that they would stabilize the ROV... But it turned out, my guess is most ROVs don't really need stabilization in that degree of freedom...

That some students withheld or did not advocate for particular ideas seems to undermine the educational goals team-based pedagogies, which is to support collaborative learning experiences by facilitating idea negotiation, evaluation, and selection. Additionally, the idea that some students withheld ideas might also point to equity issues since other students continued to advocate for ideas despite inherent flaws, a lack of explicit justification, or both. For example, Matt, who was described as a “de facto leader” on Team Mobula, noted that though he knew his individual design proposal failed to meet some design constraints, he was adamant about the degrees of freedom, and hoped to push the team toward his ideas about the degrees of freedom:

> Well, I think I just wanted more so the ideas of which direction it should be traveling in. So, definitely surge and heave, and yaw those are the only things I was adamant about. Coming to the actual team. So, I guess that's the only thing I was trying to present because I knew that something [in my IDP] was probably wrong.

Students on other focal teams articulated similar dynamics, whereby some students withheld or did not advocate for ideas due to concerns that they did not have suitable justifications. For example, unlike Team Mobula, Team Surge chose the entirety of three students' IDPs to present during their Preliminary Design Reviews. Like students in Team Mobula, multiple students in Team Surge suggested they were uneasy presenting or advocating for some ideas given an inability to support those ideas with adequate knowledge. Like Team Mobula, students' uneasiness pursuing ideas due to a lack of knowledge at the individual level also shaped early design discussions at the team level in Team Surge. For example, when I spoke with Ryan about the team's decision not to include his design, he spoke about his inability to convey ideas using adequate knowledge:

> I would say that in terms of explaining my idea to the rest of the team, it's difficult when... Me, I don't have a lot of drawing experience, so when you have something in your head that you don't even fully understand because you don't have a ton of the skills yet, and then you try to draw it, write that down or draw a sketch to explain it to other people, it doesn't always completely convey exactly what's up here just by fault of you don't have the skills to draw or explain. So, it's not frustrating, but you can definitely notice a lot of times when you're talking about your design and then somebody reiterates it to make sure they're understanding and they say something that's pretty different, and you're like, "Either I didn't explain it that well or they weren't listening." And usually, it's just like a difficulty of explaining, especially when we're all at this lower level of knowledge about the subject.

Ryan's inability to convey his ideas using technical knowledge led him to concede the team's limited PDR space to people he noted were "more attached" to their ideas—Lauren and Danish. Stephanie, who said she had "a hard time getting behind an idea when I haven't done a ton of research," articulated a nearly identical sentiment—she felt that Team Surge lacked the knowledge necessary to make a decision and ceded space in the PDR to those who were "more convinced" by their ideas:

> All I remember is that we all were arguing a lot about everything but for no reason. Not for no reason, that sounds mean. It wasn't super productive to an end because none of us really knew what we we're talking about. We weren't arguing out of malice. It was just like we'd always come back to the fact that we didn't have enough information to make a real decision, but we still had to make a decision. I think that was the main thing that we were struggling with. Because some people are more convinced in their ideas. Some people were less convinced all around. I think I was one of them.

That some students withheld ideas because they lacked confidence in their rationale while others elevated their ideas simply by being more vocal or more willing to advocate without strong justification was a pattern across the teams. The Yachtsmen, for example, chose one student's, Kyle's, IDP for their Preliminary Design Review. When I asked students why they had settled on one IDP, explanations varied. For example, Paul acknowledged that his ideas "lacked creativity," and he knew others "would have something to base things off of," a comment I return to in later sections. Kyle, on the other hand, acknowledged that he had entered the space hoping to "sell" his ideas to the team:

> And obviously, there's a little bit of you kind of want your ideas to be used. I was kind of trying to sell it to them like, "This is a good thing." And we ended up kind of going off my idea and then kind of simplifying it down into more of like the box frame instead of having it thin and wide at the back. So, I guess you're just trying to sell your ideas. I feel like I was kind of the most vocal in stepping up and sharing my idea at the beginning, and then accepting other people's ideas as kind of building off of my idea. So, then I was kind of like, "Oh yeah, we can work that into this this way," and then instead of going off of somebody else's I kind of brought that into how we could work it together I guess in a way if that makes sense.

While some students acknowledged reluctance to pursue or advocate for particular ideas in the absence of suitable justifications, others forged ahead, elevating their ideas simply by being more vocal, even without explicit rationale. This suggests the normative supremacy of

Eurocentric epistemologies does not apply equal pressures to students to adhere, underscoring the role of Eurocentric epistemologies in equity issues in engineering.

Manifestation 1 calls both Proposition 1 and Proposition 2 into question, particularly as they relate to the normative role of scientific objectivity. Specifically, it appeared that some first-year design students who adhered most heavily to the value of scientific objectivity via the need to offer explicit support were also more likely than their peers to withhold, withdraw, or to refrain from advocating for their ideas in their teams. Conversely, some students who acknowledged that they did not have adequate justification or support for their ideas appeared to elevate their ideas despite their lack of support by being “more adamant” during team meetings. These two findings seem to undermine the idea that adherence to scientific objectivity (e.g., by supporting ideas with technical math and science knowledge and reasoning) leads to greater status. Yet, it is the case that the degree to which students could support their ideas with knowledge they viewed as accepted in engineering suggests scientific objectivity *did* shape the ideas teams considered—perceived lack of knowledge stopped some students from advancing their ideas and it also influenced which ideas were discarded and which ideas were pursued.

Manifestation 2: Technical Tools as Gatekeepers to Engineering Ideas

During my observations of the three focal teams, the role of technical tools, particularly each team’s CAD model, became a recurring theme in each team’s work. In the focal teams, control of the CAD model made particular students who were assigned the task an implicit or explicit gatekeeper to ideas. In later sections, I discuss how students’ confidence with CAD modeling software, and concerns about the ability to defend ideas using the software, shaped how teams selected ideas and delegated tasks. Moreover, I describe moments in which students who were delegated their team's CAD model appeared to exert influence over the team during the project.

Team Surge was unique amongst the three focal teams in their struggles with SolidWorks, the computer-aided design (CAD) software wherein students generated models of their concepts for presentations such as the DDR. Whereas the preliminary design review did not require a CAD model of the team's design, the CAD model was a central requirement for the DDR. For this reason, the team's struggles with SolidWorks became an important factor in the ideas the team chose to pursue.

For example, following the contentious meeting about the team's frame, the team tentatively decided to pursue the Trapezoid Frame and assigned the CAD model to Stephanie to complete. Over the course of the following days, the team determined that the design of the Trapezoid Frame entailed extensive SolidWorks work, as well as the development of custom parts using 3-D printing. Rather than continue to struggle to implement the design in SolidWorks, a time-consuming exercise that the team realized might ultimately be fruitless, the team adapted their design and ultimately abandoned the Trapezoid Frame idea. Stephanie reflected on the process as follows:

> I tried to build it [i.e., the Trapezoid Frame] on CAD. I have negative CAD experience. I liked trying it. I'm really happy that I got that experience, but it was really hard and really, really frustrating to try and do. I wound up figuring it out. I messed up all the dimensions and it was really fat and big and unnecessarily so. We realized we'd have to make custom joints at 135 degrees with a 90-degree thing. We'd have to 3D print those and then we got scared away from that in the lab. Sometimes, it just doesn't work.
>
> That's not ideal for us. Lauren came up with that idea, which she had already had mentioned I think it was right after I finished the CAD or right before. Honestly, no one really thought much of it and then we were like, "This is not going to work." Lauren presented her idea again and everyone was like, "Okay. Let's do that." It wound up working out really well. It was a lot easier. I honestly think it might even be easier than doing something completely rectangular because it opens up the space a lot, which I would have really liked to actually have built that.

On its own, the finding that technical tools such as CAD software were gatekeepers to ideas does not point to the normative supremacy of Eurocentric epistemologies in engineering, particularly given that this was a requirement of the DDR assignment. Still, I discuss the role of technical tools to point to patterns of influence on the team. For example, after the instructors granted Team Surge approval to *build* their ROV concepts using hand-drawn sketches, the team resisted their peer mentor's advice to begin building their frame, insisting instead on developing the CAD model, an exchange I documented in my fieldnotes:

> The team began discussing their build plan. They quickly agreed that, though they had won approval, they would not start building today. Ryan and Stephanie were the most concerned that the numbers [i.e., dimensions] were not finalized. [Peer mentor] said that this did not really matter and that the team could always try it and adjust. [Peer mentor] told the team they can use their drawing to get going. Ryan objected—he felt strongly that they should finalize the dimensions, but [peer mentor] (with agreement from Rehman) told them that they can use the dimensions they have already negotiated and described to the instructors…"but fine, if it will make you more confident, CAD it up and measure it to be sure."

I returned to this interaction during the individual interviews and asked students on Team Surge to reflect on the central role their CAD model played in shaping their ideas and building process. Ryan, who was adamant that the team finalize their CAD model before beginning their building tasks, reflected both on the course requirements, as well as the role of technical tools in organizing the team's ideas:

> I think the CAD model was important just specifically for presentations and stuff. We needed to have the CAD model to show, but also in terms of group understanding, I feel like personally until you have a full 3D model of like, here's where each one of these things are, still there was some maybe inconsistencies where we thought each item was, even if we had talked about it just because we're not great drawers I guess. That was one of the most, I think important things of the CAD model is just finally being able to say, "Here you can see every single side, you can see it from several different aspect ranges or you can see it from diagonal top, or behind, or underneath." So being able to actually have a realistic model as opposed to drawing boxes was important to getting the team on the same page.

Ryan’s suggestion that the CAD model played a central role in finalizing the team’s understanding of their design was particularly interesting given the almost sole role he played in developing the model. While Stephanie had initially been assigned the CAD model, Ryan took on the task following the team’s struggles to implement their ideas in SolidWorks. During one meeting, Ryan explicitly told the team that he did not want anyone to touch the model because he had done “a lot of bogus things to get it to work,” and he was concerned about problems others might have if they tried to make adjustments. Like other teams, Ryan’s control over the CAD model gave him implicit influence over the design process.

Like Team Surge, the role of technical tools in shaping The Yachtsmen’s design process also became prominent as the team prepared for the Detailed Design Review presentations. Like Team Surge, the four more active members of The Yachtsmen became hampered by limitations in their SolidWorks skills. For example, during one meeting, after the team had sketched a complete model of their final ROV, John’s progress developing the team’s CAD model was impeded by his and others’ skills in the software. After John recalled the team-building exercise from the team’s first meeting, during which Cam indicated he brought CAD modeling skills to the team, The Yachtsmen turned to Cam for support developing the model. By the end of the meeting, the team had delegated the CAD model of the team’s ROV to Cam almost entirely.

The decision to delegate the CAD model to Cam came with significant consequences. First, during both the meeting and his interview, Kyle noted that he had been interested in working on the CAD model but decided to delegate the task to Cam since it appeared to get Cam more involved in the team. Indeed, after the team delegated the CAD model to Cam, I documented his more active role in the team’s design decisions.

Additionally, the person developing the CAD model became a significant gatekeeper to ideas over the course of the project. As I observed The Yachtsmen develop and clarify their design in preparation for the CDR, I noted multiple points in which Cam's control over the CAD model resulted in tacit influence over the team's decisions. I documented multiple discussions during which Cam's teammates offered ideas for modifications to the design, which would entail modifications to the CAD model, that resulted in significant pushback from Cam and, at times, unilateral decisions by Cam. John, for example provided a summative description of Cam's role on the team leading to and following the delegation of the CAD model:

> There was an odd instance in which…so he had the responsibility of finishing our CAD model for our ROV, so the team came to him and said, "Okay, so we've decided on this, this, this, and this for the model." Then when he CADed it up, only like two of the things that we asked for were on it. So that was interesting because we didn't want to be like hey, Cam, you didn't do what we wanted. But we also didn't want to come off as like we're ordering you to do this. We didn't want to be mean to him. But it all got worked out in the end.

Across the teams, technical tools such as CAD software played a significant role in the ways that students approached the design process. The need to implement ideas in CAD software (e.g., SolidWorks) shaped the ideas teams pursued (see Team Surge). More importantly, the person responsible for the CAD model often became a gatekeeper for ideas. In the case of Team Surge, the inability to implement particular ideas in SolidWorks led the team to consider different ideas. For The Yachtsmen, the person controlling the CAD model, Cam, was able to exert *influence* over the team's decision by deciding, at times unilaterally, how ideas would be implemented in the team's model.

The ways that Cam exerted influence using the CAD model recalled the normative supremacy of Eurocentric epistemologies. Ideas that would need to be implemented in SolidWorks required work from Cam. As a result, I documented moments in which the team appeared to defend their ideas to Cam specifically. For example, during one exchange, I documented the very different approaches Kyle used to defend an idea to Cam, who would need to implement the idea should it win approval:

> Kyle discussed a design issue related to thruster placement. I noticed that he pitched the idea to Paul first, arguing, "if we move these [thrusters] a little bit, they wouldn't pitch as much." Hearing Kyle and Paul discuss changes to the design, Cam then joined the conversation, and Kyle re-presented the idea to him.
>
> Kyle: If we move these [heave thrusters] up, they will be in line with the center of buoyancy and it won't pitch as much."

I was interested in this translation between the two explanations—the first relying on intuition and the second relying on a more technical explanation. Recall that, in SCT, influence may be conscious or unconscious (Simpson, Willer, & Ridgeway, 2012). That Cam became a gatekeeper for ideas, and that the "cost of admissions" was, implicitly, communicating ideas in terms of mathematics and scientific knowledge suggests both that Cam emerged as an influential actor on the team and that Eurocentric epistemologies was one way that Cam wielded influence on the team. Interestingly, Cam endorsed statements in the engineering-related beliefs (ERB) scales about the normative supremacy of Eurocentric epistemologies far more than his teammates at the start of the term. More importantly, Cam's influence was another way that Eurocentric epistemologies do not exert equal pressures on all students. Cam, for example, did not need to defend his own ideas to himself or his teammates using math and science in order to get those ideas included in the CAD model.

The finding that technical tools, most prominently CAD models, might serve as gatekeepers to ideas is not directly related to the propositions posited in Chapter 2. However, the ways that students understood the role CAD models played in their team decision making was an unanticipated illustration of how Eurocentric epistemic values shape scientific and technical work. For example, several students articulated that CAD models clarified their team's concepts so that everyone on the team was "on the same page." Similarly, students articulated that numbers and dimensions were not finalized unless the same dimensions in hand drawings, which were accepted by the instructional staff as suitable for winning approval to advance in the project, were implemented in computer models (i.e., CAD models). These comments point to students' assessments of appropriate knowledge and adequate support for communicating information.

Moreover, the processes by which students elevated technical ideas in conversations with their peers evoked Proposition 4, which posits that adhering to scientific objectivity might result in greater influence on design teams. In contrast to Proposition 1 and 2, which focus on status in teams, Proposition 4 focuses on how scientific objectivity is related to influence—the process by which students communicated or interacted during the design process to shape the opinions, decisions, and behaviors of their team. During my observations, for example, I documented how Kyle turned to technical language to elevate his ideas to the implicit gatekeeper (i.e., Cam, the person delegated the CAD model), which suggests that scientific objectivity shaped the process by which ideas were communicated, agreed upon, and implemented. Moreover, just as shown in the description of Manifestation 1, some students (e.g., the student in charge of the CAD model; more confident students) influenced team decisions without communicating ideas using math and science, or without communicating ideas at all. This suggests that the need to adhere to scientific objectivity was not felt equally by all students and in terms of influence on first year design team, nor it did not apply equally to all students.

Manifestation 3: Rhetorical Shifts

I began revisiting the assumptions of Proposition 1 and 2 about the relationships between adherence to Eurocentric epistemologies in engineering and relative status on teams during my observations of the three focal teams. As noted above, I saw that it was not always those students who relied heavily on technical, mathematical, or scientific knowledge who appeared to be influential actors. In fact, there were times when influential actors on a team navigated the design process without adhering to Eurocentric epistemologies. Conversely, I noticed students leaned on mathematics and science concepts in moments in which their ideas were being challenged. As a result, I documented *rhetorical shifts*, which I defined as moments in which students presented their ideas using multiple arguments and, in particular, multiple sources of knowledge. In these moments, students appeared to *scientize* their ideas following pushback or outright objections from their teammates or other audiences. For example, during a team meeting The Yachtsmen engaged in a discussion about a critical design priority—the degrees of freedom they wanted to prioritize in their design (e.g., surge, heave, yaw, sway). John repeatedly argued that the team should not use any of their thrusters for sway. In trying to convince the team, he changed his arguments several times:

> At multiple points in the conversation, John suggested the team will not need sway thrusters. This point, at first, was not acknowledged at all. Later, the team returned to the idea, but the team did not make any decisions about the argument (i.e., the point was left without conclusion). Finally, John approached the whiteboard and drew out his concept to include an argument against sway thrusters. It was not immediately clear how the sketch advanced his argument against the use of a sway thruster, and again, John's sketch failed to move the team. Finally, the team (particularly Kyle and Paul) took up the idea, and the team, at least preliminarily, decided they will not need sway thrusters.

John's resistance to the dedication of a thruster to sway took on a number of forms before he was finally able to get the team to somewhat agree. First, he simply explicitly articulated his opposition to sway thrusters as "unnecessary." Next, he took to the board to sketch an ROV, arguing for why sway thrusters would not be necessary. During his work at the board, John asked the team to consider both “sway vs. no sway”, articulating the issue as a design dilemma. Third, he rearticulated the argument in terms of the technical aspects that the inclusion of sway thrusters might entail, saying that the sway thrusters “increase the complexity of the design and requires way more math.”

Later, as the team engaged in a similar discussion about whether how to achieve yaw, as well as the placement of their thrusters, John, again, made a similar rhetorical shift. In this discussion he again presented an idea, and after it is was not acknowledge, he again tried to “scientize it”—or at least allude to scientific knowledge. John did not describe the details of the math and science behind his arguments. Rather, he alluded to them by using particular terms—power, torque, “way more math”—perhaps for credibility.

John’s pivoting to technical knowledge to gain legitimacy was a pattern throughout my observations of The Yachtsmen. Perhaps the most noteworthy occasion occurred as the team presented their Detailed Design Review (DDR), during which John was tasked with presenting the team’s custom part—a thruster shroud John had taken the lead in designing. Prior to the DDR presentations, I observed The Yachtsmen practice their presentation to an audience that consisted of myself and their peer mentor. During the practice presentation, the students drew on different types of information when presenting their team’s ideas. For example, John chose to focus on a more general description of the thruster shrouds, describing the purpose of the idea rather than a technical justification for whether the idea would work.

However, during the DDR presentations, Team Mobula, which presented just before The Yachtsmen, had received negative feedback on their similar custom thruster shroud. As I watched Team Mobula address the negative feedback on their custom part, I wondered how the negative feedback Team Mobula received might be perceived by The Yachtsmen and in particular by John. Prior to the presentation, The Yachtsmen had a quiet discussion before they were called to present, and I wondered if they, and John in particular, might choose to change the information they included in the presentation in response to the criticism they saw Team Mobula receive. This became apparent when The Yachtsmen presented their DDR, and John changed the way he presented the team's custom part:

> John appeared to address his presentation directly at [the two experts who were invited to provide feedback][9], who had just put Team Mobula through the wringer. He made almost constant eye contact with our table... As he presented, I also noted that John's presentation was noticeably different than his description during the practice presentation. John focused his presentation on how their team's design addressed some of the shortcomings that [the experts] had discussed in Team Mobula's custom part. Though he never cited any of the research, he made multiple references to the idea that their design was based on "research we did", and he changed his approach to describing the part. Whereas Kevin (Team Mobula) said that he'd hoped the part would decrease drag and increase efficiency, which the "experts" in the room objected to, John's explanation seemed aimed at circumventing that particular criticism. He explicitly said they were not worried about drag, and that their design still allowed water flow.

Here, again, John changed his explanation of an idea, drawing particularly on technical engineering knowledge—in this case, Authority by way of an allusion to "research," as well as addressing specific technical issues—in order to circumvent criticism and gain legitimacy. I spoke with John after class to understand his thoughts on the presentation and asked specifically why he had changed his presentation:

> I asked John, "on a scale of 1-10 how freaked out were you after the presentation before you?" He said "I was definitely nervous at the beginning, but after a bit I settled in." He noted how, after the questions Kevin got during Team Mobula's presentation, he thought about how he might focus on specific aspects of their [i.e., The Yachtsmen's] design that were different than Kevin's to defend his ideas, confirming my suspicions that he'd modified his presentation strategically to gain legitimacy in light of what he had observed during Team Mobula's presentation.

---

[9] Since these two experts were not participants in this research, as defined by Institutional Review Board agreements, I abstain from naming or describing them in detail.

Here, I suggest that pivots in the sources of knowledge students draw on when defending their ideas to different audiences is an implicit recognition of the normative supremacy of Eurocentric epistemologies in engineering, including the normative supremacy of mathematics and science, as well as deference to authority regarding engineering knowledge. The ways that John chose to participate in the design process, both during his team discussions as well as during the DDR, suggest that John pivoted precisely because he understood that particular sources of knowledge would be more valued or legitimate, and assumed that he might win approval by using, or alluding to, technical knowledge in order elevate the ideas he was defending.

The pattern of using rhetorical shifts to elevate ideas was common across the focal teams. During Team Surge's PDR Danish asserted that the team was "definitely leaning towards" the "Trapezoid Frame" that had been the result of his IDP. However, in the meetings following the PDR, it became clear that Danish's assertion was not shared by other members of the team. The discussion of, and at time resistance to, Danish's Trapezoid Frame was a theme of the meeting, and the ways that Danish convinced the team to pursue the design recalled the normative supremacy of Eurocentric epistemologies in engineering, particularly via rhetorical shifts in moments when their ideas were undermined. In particular, as Danish began his attempts to convince the team to pursue the Trapezoid Frame, there was a surprising lack of technical justification in the team's discussion, culminating in an open admission that the team, to that point, had been guided by intuition and guesswork.

A number of times the students indicated that they made judgments based on intuition. For example, while Stephanie was arguing against the cube front, Danish responded, "Based on my intuition, I agree!" Though it was often unspoken, there was a lot of postulating based on intuition. At one point, Stephanie laid this bare when she asked how they knew which concept would be most affected by drag. No one could answer the questions definitively, so Ryan replied, "That's a great question!"–implying he could not articulate a suitable answer.

Stephanie's demand for a justification for each idea was followed by one of the few technical turns that I observed in Team Surge. In particular, Danish took the opportunity to revise his justification for the Trapezoid Frame, seizing on mathematics and scientific knowledge to push the team back toward his preferred design. I wrote:

> Danish, who favors the trapezoid design from his Individual Design Proposal, pressed the team to name the negative aspects of the trapezoid design. The team began to name several drawbacks—the trapezoid frame required more PVC and it is likely more difficult to build because of the need for custom joints. However, when Lauren suggested it "is more hydrodynamically stable," Danish pounced on the use of technical terms to describe a benefit of the design. He quickly seized on the comment and began to write out (seemingly arbitrary) mathematics (i.e., trigonometry) concepts on the board to push the team back toward the trapezoid design. The team later added that the Trapezoid Design might reduce drag.

As I documented these moments, I wondered if these were purposeful, strategic decisions students made in order to elevate ideas by referencing mathematics and science in engineering. In this exchange on Team Surge, students used incorrect or incomplete applications of technical knowledge, indicating it was not the veracity of the technical knowledge that won over their teammates, but the mere presence of that knowledge. In those moments, I wondered if the normative supremacy of Eurocentric epistemologies informed an intentional method of wielding power and influence.

To explore whether Danish's rhetorical shift was strategic, I asked Danish to reflect on moments in which he used technical knowledge in conversations with his team. He acknowledged that he had used technical knowledge strategically in moments in which his team had pushed back against his idea.

> The only times I was really technical, I think was when I was defending something, or advocating for something which was being fought against, in terms of design. Like if I was trying to get some kind of reasoning as to why this was better for design than the other thing, then I would try and be more technical about it, get something more discrete. I feel like technicalities are less easily argued against, because they're closer to right or wrong than an idea, or an opinion for certain.

Danish's indication that he relied on technical knowledge particularly in moments in which he believed Team Surge was poised to discredit or discard his ideas offers support for the notion that the normative supremacy of Eurocentric epistemologies informs how individuals approach design in team settings. Moreover, there was a connection between John's approach in The Yachtsmen and Danish's approach in Team Surge—they both turned to technical knowledge when they perceived their ideas were under threat to gain legitimacy. In both cases, the result of these rhetorical shifts was such that their ideas escaped further criticism and scrutiny. Team Surge, at least initially, chose to pursue Danish's Trapezoid Design, and John was able to convince his team to at least table the discussion of the sway thruster. This similarly suggests that these behaviors resulted from students' understanding that their teammates might defer to dominant epistemologies during design disputes. Moments during which students appeared to shift their arguments particularly when their ideas were under threat of being discarded made me revisit the idea of whether it was adherence to Eurocentric epistemologies that led to status on the team or whether it was a lack of status that led to adherence to Eurocentric epistemologies.

Rhetorical shifts during design discussions offered support for several of the propositions posited in Chapter 2. For example, there is evidence that students "scientized" their ideas to exert influence in their teams. This supports the idea that students' whose epistemological perspectives align with dominant Eurocentric epistemologies become high-status members who might take, or be granted, more action opportunities during the design process (i.e., Propositions 1 and 2). During the contentious debate around the design Team Surge should pursue, it was Danish's ability or willingness to translate and communicate his ideas using technical engineering knowledge that won him the opportunity to pursue his Trapezoid Frame further during the design meeting. Moreover, this episode also provides support for Proposition 4—that adhering to scientific objectivity is one way that a student could wield influence on a team. Danish's decision to communicate his ideas using math and science concepts in a moment during which he perceived that his ideas were being "fought against" convinced his team to pursue his idea, which suggests that adhering to scientific objectivity was one way that students could modify the opinions, decisions, and behaviors of their peers. Importantly then, rhetorical shifts represented an implicit recognition that particular sources of knowledge (i.e., technical math and science knowledge) might be more convincing or highly regarded.

Manifestation 4: Meticulous Preparation

In the pilot study, I was sensitized to the possibility that some students felt compelled to develop their ideas thoroughly away from their teams to pre-empt the discrediting of their ideas by their teammates. Conversely, other students felt free to "throw ideas against the wall" in their team meetings. As one student phrased it, some students felt accountable to their own ideas, working to clarify their ideas in advance, while others entered underdeveloped ideas for their team to discuss, thereby putting the responsibility on the team to flesh the idea out.

While some might argue that meticulous preparation is an indicator of good engineering work, I argue that this might be an insidious manifestation of the normative supremacy of Eurocentric epistemologies and how they are leveraged or weaponized to marginalize some students in engineering. As I observed the three focal teams, I documented moments in which students appeared to hold themselves accountable to particular ideas, when students placed that responsibility on their teammates, and the effects these moments appeared to have on the ideas that were elevated, marginalized, or discarded.

In previous sections I showed that some students felt free to discuss and pursue ideas without technical support while others felt accountable to their ideas and understood that their ideas needed to be “fleshed out” before they could win approval from their teams. While Team Surge initially decided to pursue Danish’s Trapezoid Frame, challenges implementing the Trapezoid Frame, including the team’s lack of knowledge and skills related to developing CAD models in SolidWorks® and difficulty developing the custom joints that would be necessary for the idea, led the team to decide to pursue other options for the frame.

During one class session, I noticed Lauren had sketched a new frame, one that kept many of the features of the trapezoid design but alleviated the problem of having to develop custom joints. As I observed the team, I considered asking Lauren for a photo of her sketch. However, as the meeting went on, I became perturbed that, though the sketch appeared complete, Lauren did not share the idea with her teammates. As the class period adjourned, the new design went unshared with the rest of Team Surge.

Several days later, during the Thursday Technical Communications session reserved for open work time, I observed Lauren bring the sketch back to the team. This time, Lauren commandeered a whiteboard and began to sketch the new frame design on the board complete with measurements and trigonometric calculations that she completed during a discussion with Ryan. As I observed Lauren describe her new frame idea to Ryan and the other members of Team Surge, I began to wonder if she strategically withheld the idea. I returned to this with Lauren during the Design Experience Interviews at the end of the term, and she noted a number of factors that informed her approach to communicating the new design to Team Surge. First, Lauren explained that she had hoped to avoid arguments over changes to the frame, even though the team openly recognized changes were necessary to the initial trapezoid frame:

> I think, for me, obviously, I was more against it [the Trapezoid Frame], but it had gotten to a point where I just felt like I didn't want to really argue with everyone over this design. We had already put in so much discussion, and a lot of people seemed to ... the people who did believe in it really believed in it. Also, I think Danish, I think he really, really wanted to have pieces of his design included. We had to cut out different parts of people's designs…I think that was really his piece. I don't know. It [the Trapezoid Frame] was new, and interesting, and I guess I didn't really want to argue about why it shouldn't be included…because…it was the main feature of his. Then, also, again, it was a different frame, and we wanted to go for that creativity factor.

Lauren went on to say that she took the time to clarify the idea by refining the dimensions and developing justifications for her design prior to exploring with the team. Lauren also spoke about her strategic process for conveying the idea to the team:

> Stephanie was trying to get the CAD design done, and obviously, the custom joints were just not working. I was just thinking what joints were available and what we could do with that. I figured the trapezoidal frame, it had too many sides, so reducing the number of sides would make it easier, like more simple. Then, I just figured out what dimensions we would need to have to use the 135 degree joints…I also mentioned to Stephanie I had an idea that might make it easier... I decided to just draw it up, and wait until I could see people in person, because I figured trying to have that kind of discussion over chat would not go over well, and people, I think, just the difficulty of trying to convey your ideas and get people on board, it's just so much harder over text.

She continued:

> I really wanted people to hear me out, because I thought it was a really good idea, and it would solve all our problems. I explained everything. I took highlighters, and I tried to make it really, really clear, so people could really see what I was trying to say. They liked it. It went over well. I just described all the things. I had all of the joints and parts that would be needed listed and gave my rationale. Then, I think we talked it over a bit, but people were pretty much pretty quick to get on board with the idea.

Lauren’s suggestion that she clarified the idea in order to ensure she was heard seemed to align with the propositions informing this study—adhering to Eurocentric epistemologies was one way to elevate her ideas. As Lauren discussed her experience sharing ideas, I asked her if she had felt as though she struggled to be heard. As she spoke, I heard similar concerns to a student from the pilot study, namely, that she felt compelled to clarify her ideas before putting them before the team, and that clarifying ideas might help her be heard on the team:

> If I had an idea, and it wasn't being heard, it was more something that I was iffy on. It was less about ideas, I guess. I did feel like I wasn't really being heard with some of the design report decisions. It felt like I was giving out a lot of ideas. Ryan would be the one to say, "I don't think we should do that." Actually, we talked about it. I messaged him. I'm like, "I'm getting frustrated. I feel like my ideas aren't being heard, and it's kind of unfair."

It might be considered a good thing that Lauren clarified her ideas before presenting them to the rest of Team Surge. Such efforts might increase efficiency by saving meeting time, for example. However, I argue that this might constitute an undue burden on Lauren, a mechanism by which the normative supremacy of Eurocentric epistemologies applies a burden on some students in ways that are not necessarily felt by others. Lauren came to a meeting completely prepared with a clarified concept to present to her team. The burden on Lauren to be accountable to her ideas did not appear to be shouldered by Danish in the same way. Team Surge spent an entire meeting discussing and clarifying Danish's Trapezoid Frame idea, which the team, at least initially, chose to pursue as a result of that meeting. While the team eventually chose Lauren's revised frame due to implementation issues with the Trapezoid Frame, that Danish could elevate his idea without the same preparation Lauren brought points to equity issues in their team.

Lauren's meticulous preparation was a pattern I also observed during the pilot study. I contend that the nature of this preparation points to the normative supremacy of Eurocentric epistemologies. Proposition 1 and Proposition 4 state that adhering to scientific objectivity might lead to higher status and greater influence during the design process. That Lauren viewed meticulous preparation (e.g., clarifying dimensions and parts alone ahead of meetings, eliciting feedback from peers prior to communicating ideas) as a mechanism for ensuring she was heard suggests an implicit recognition that adequate support—not appearing to be "iffy" on her ideas—

was a way to protect her ideas from being undermined by team members. Lauren appeared to view her meticulous preparation as a method of elevating her status (i.e., being heard) and wielding influence (i.e., modifying opinions, decisions, and behaviors of the team), offering support for Proposition 1 and Proposition 4.

Moreover, that it was a woman on the team who articulated that preparation was a way to ensure that her teammates might "hear her out" offers some support for Proposition 5, which posits that characteristics such as race and gender will result in varying patterns related to the degree to which adherence to Eurocentric epistemologies result in higher status on design teams. That Team Surge used an entire meeting to clarify the Danish's Trapezoid Frame, while Lauren felt the need to clarify her ideas to be heard, suggests the normative supremacy of scientific objectivity, while present in both their approaches to the team's design process (see: Danish's rhetorical shifts), resulted in different behaviors during the team's design process.

Manifestation 5: The Nature and Use of Questions

As I observed teams I also documented the questions students asked (e.g., of themselves, of their teammates, of authority figures) in their design process, in part, because the tone and timbre of some focal students' questions, combined with body language and context, suggested that the questions might effectively function as methods of wielding influence over the design process. I categorized questions into three broad categories—hedging, attacking, and elaborating questions that seemed indicative of relative status and influence on teams.

Hedging Questions

In SCT, individuals with status are understood as having the ability to utilize conscious or unconscious social pressures to modify opinions, expectations, decisions, or behaviors of others (Simpson, Willer, & Ridgeway, 2012). My analysis of the first category of questions, which I call hedging questions, includes moments in which students redirected discussions or behaviors by inserting new or different ideas via questions to the team. These questions were rarely used by those students seen as leaders of their team. Instead, the use of hedging questions appeared to be particularly frequent amongst students who lacked authority, either in the moment or in general over the course of the project, in their respective teams.

For example, during one team meeting, the Yachtsmen were engaged in a discussion during which the team sought to clarify the major aspects of their design, including dimensions, as well as thruster and payload placement. During the discussion, Kyle, who routinely took the lead during team discussions, began to sketch the team's ROV design on a white board. As the team discussed the ROV's dimensions and placement of various components, I noticed Seth insert a hedging question—"Aren't we putting the thrusters on the outside?"

If one were to simply analyze the utterance, it would appear that Seth was simply affirming the team's ideas as they discussed them. However, Seth's tone and timbre, combined with the context of the utterance (i.e., the sketch Kyle has drawn that included thrusters on the *inside* of the frame), made it clear that this was Seth's way of expressing disagreement with Kyle's sketch, and redirecting the conversation from a discussion of dimensions to a discussion about thruster placement. As the team continued their discussion, these hedging questions were most often used by students who wavered as they discussed ideas, the meeting's agenda, or design-related tasks. As I looked to the questions that I perceived to be hedging questions across the teams, I noticed that hedging questions were used, in particular, by students who were not described as "leaders" on their teams. During interviews Matt and Kevin were described as implicit and *de facto* leaders of Team Mobula. Similarly, members of Team Surge acknowledged Ryan's leadership role on their team's final design, particularly as it related to his work on the team's CAD model, and members of The Yachtsmen acknowledged Kyle's influence on their team, particularly as it related to the use of his IDP as the basis of their final design. As I coded *hedging questions*, I noticed that these questions were rarely used by those students seen as leaders of their team. Instead, this type of question was often used by low-status members, seemingly as a method of exerting influence without direct, perhaps confrontational means.

Non-confrontational hedging questions appeared in other settings during the design process. After the team presented their initial ideas in their PDR, I documented an exchange between Chelsea and the Technical Communications instructor, Heather. As the team discussed their open issues slide, I noticed that Chelsea re-worded some questions during the discussion. For example, while the slide read, "Will certain thruster placements suffer from obstructed water flow?", Chelsea re-worded the question, asking if restricted water flow might be a problem for heave thrusters on two of the three designs the team had presented.

At first glance, Chelsea's concerns about the water flow on two of the three designs appears to be a reasonable, earnest attempt to gather information about the team's potential designs. However, during an informal interview following Team Mobula's PDR, Heather (i.e., the Technical Communications instructor) wondered aloud if this was a familiar tactic we had discussed during the pilot phase, wherein students use negatively-framed questions to discredit particular ideas and elevate others. Chelsea's questions voiced her concerns about ROV-2 and ROV-3 from the team's discussion, and Heather wondered if Chelsea's individual design proposal might have informed ROV-1 in the team's PDR. Upon review, Heather suggested ROV-1 appeared to heavily resemble Chelsea's design proposal, suggesting Chelsea's questions might have been *hedging questions* designed to elevate her ideas from ROV-1.

I returned to this moment during Chelsea's design experience interview. During the interview Chelsea acknowledged that she had not been confident about various aspects of the individual design proposal process, but that she was "confident-ish" about her choice of thruster placement. She acknowledged that the decision on thruster placement had been narrowed to two choices—the "two and two" idea (represented by ROV-1) and the one heave, one sway idea (represented by ROV-2 and ROV-3)—but that it was "tough to come to a decision because [Team Mobula] couldn't rule out either one for being a bad idea." Chelsea noted that the decision Team Mobula affirmed the "two and two" idea only after Kevin changed his position, and the "two and two" idea had majority support.

I argue students' use, or lack thereof, of hedging questions reflects relative status on teams. Still, I do not argue that they point to an elevation or rejection of the normative supremacy of Eurocentric epistemologies in engineering. While one might argue that Chelsea's negatively framed questions to Heather were an implicit use of *authority* (i.e., Heather as authority figure) to influence the team's decision, the connections to Eurocentric epistemologies in hedging questions were often less clear, and thus I drew no conclusions about such connections during my study. Instead, I argue the two other types of questions I documented—attacking and elaborating questions—were methods by which the normative supremacy of Eurocentric epistemologies in engineering shaped hierarchies in teams.

Attacking Questions

The second category of questions, *attacking questions*, generally signaled opposition to ideas or courses of action and often precipitated the discarding of ideas in the focal teams. Often, attacking questions did not feature elevated voices, aggressive body language, or antagonistic behaviors. Instead, it was a method for influential actors to exert influence over the behaviors and decisions of an actor with less power. Attacking questions featured heavily in moments of inconsistent scrutiny, where one student's work or ideas were scrutinized and altered or discarded while other students' work escaped the same level of scrutiny.

For example, prior to one of the laboratory sessions required for the course, students were tasked with designing a "concept vessel"—a "practice" ROV frame that they would build during the week's laboratory session. The concept vessel had no relation to each student's individual design proposal, nor did it have any relation to the team's final design. The purpose of the activity was to facilitate students' experience learning to use various pieces of laboratory equipment (e.g., circular saw, hydraulic nail press) as they built the otherwise useless practice ROV frame. I observed Team Mobula during this assignment, including their process of choosing a concept vessel to build during the session. The instructional assistant suggested each team either choose one person's concept vessel, combine features of multiple concept vessels, or modify one or more vessels to build during the class.

Because the concept vessel had no use outside of the activity, Matt suggested the team choose only one of the five concept vessels and led the team in a review each person's concept. Addy began by showing the team images of the concept vessel that she had designed, and I noticed a set of *attacking questions* from her teammates scrutinizing her concept vessel. Chelsea began by asking Addy if she was sure her concept vessel met all of the requirements for the assignment. When Addy responded that she felt confident her concept vessel did meet all of the requirements, Matt followed by further scrutinizing the concept vessel, checking it against the requirements and concluding that at least one dimension was outside of the requirements outlined in the document. Addy's concept vessel was discarded as a result.

If it had been the case that the team scrutinized all each other's ideas the way they scrutinized Addy's concept, one might conclude that this was good engineering work or that this level of scrutiny might lead to better concepts. However, this was not the case for Team Mobula. After deciding not to pursue Addy's concept vessel, Team Mobula turned their attention to Kevin's presentation of his design, which did not receive the same scrutiny as Addy's. Like Addy, Kevin showed the team images of his concept vessel. Matt immediately responded with "Oh! That looks good!" Max followed by noting that Kevin's concept vessel looked similar to his own. The team quickly chose to pursue Kevin's vessel after their short discussion. No one bothered to ask about the dimensions until the Instructional Assistant joined the team to review the vessel. Matt then pulled up the parts requirements to verify that it met other requirements (e.g., the number of joints), and there was a discussion of PVC lengths (6 vs. 5 inches). Ultimately, the team chose Kevin's concept vessel to build during the lab.

The inconsistent level of scrutiny, as well as overt demands for justifications via attacking questions was a pattern I documented across the focal teams. Still, I do not mean to suggest attacking questions were necessarily malicious. Again, attacking questions, in general, did not feature elevated voices, aggressive body language, or antagonistic behaviors. Indeed, upon observing this interaction, I struggled to characterize the discussion, and it was not until the broader pattern of scrutiny and rejection became clear that I returned to this interaction and was able to characterize the exchange as "attacking questions." Matt's and Chelsea's tone and timbre appeared calm and neutral, even as they engaged in a process of undermining Addy's design.

Other examples during which attacking questions did not feature aggressive body language or antagonistic behaviors included moments during which negatively framed questions appeared to discredit particular ideas, elevate other ideas, or both. For example, during a Team

Surge meeting, when the team was considering the Trapezoid Frame (proposed and supported by Danish, but opposed by Lauren and others), and a simpler cube shaped frame, Danish and Rehman began to scrutinize the cube-faced frame, asking negatively framed questions (e.g., doesn't it have X problem?) to the team during their questioning. As Danish asked his questions, the team spent time sketching the idea on the board, which they scrutinized further. Later, Danish began to ask questions about the case in which the idea might be taken up by the team: "What if it leaks water? I feel like if we go with this one, we should be sure it leaks minimal water." Again, these questions were not antagonistic, but had the effect of undermining the cube-faced frame. Ultimately, the team chose the Trapezoid Frame as their tentative frame.

However, some attacking questions were less opaque during the discussions in the focal teams, and, again, I noticed how the normative supremacy of Eurocentric epistemologies accompanied these attacking questions in ways that shaped design disputes in teams. One such example occurred during a laboratory session with Team Surge. Students were presented with the opportunity to "hollow out" joints for their ROV such that some joints were more easily adjustable; however, only the laboratory instructors were allowed to use the machinery necessary. As a result, the instructors limited the number of joints teams could request to be adjusted to four, requiring teams that pursued this option to carefully choose which joints to adjust. Team Surge's initial design required 8 such joints, leading to a contentious dispute around the decision:

> Rehman offered that he is worried the design won't be sturdy enough if they don't use the hollowed-out joints in the center-back position. Stephanie dismissed this idea— "that won't matter because we'll have glue." Rehman responded, "How do you even know that (it will be sturdy enough)!?" As the argument continued, Rehman became incredulous about Stephanie's claim— "It's not going to be sturdy. It's not going to be sturdy!" When Stephanie responded to his frustration— "It won't matter there!"—Rehman again demanded an explanation. "Why!? WHY!?" He never got an answer, but he turned to Ryan at the CAD model to argue his case.

Neither Rehman nor Stephanie offered an explanation or justification for their respective ideas, making the fact that Stephanie was rather pointedly asked to justify her position—"How do you even know that!?"—while Rehman was allowed to argue his point without justification all the more interesting. In the moment of a contentious debate—it was Stephanie who was saddled with the burden of proof for her position.

Again, one might argue that it is a marker of good teamwork when teammates question each other's ideas and clarify concepts as a team, a point that I do not necessarily disagree with. However, it is the inequity of the demand—that the attacking question made the demand to justify a perspective of one person but not the other—that suggests the weight of adhering to Eurocentric epistemologies is not shared equally by all on the team. Moreover, these episodes represent moments in which the normative supremacy of Eurocentric epistemologies inform the ways students exert influence in engineering teams. Here the assumption appeared to be that the team would move away from Stephanie's ideas in the absence of suitable support. In the absence of legitimate knowledge, an idea is unlikely to be elevated. In this way attacking questions represent one way that Eurocentric epistemologies are weaponized to marginalize particular ideas.

Elaborating Questions

Elaborating questions were seemingly earnest questions students used to seek clarity on concepts and ideas. Unlike attacking questions, elaborating questions generally signaled support, or at least consideration, for particular ideas. Moreover, these types of elaborating questions featured heavily in moments during which the teams made definitive decisions about their designs.

For example, I observed a Yachtsmen meeting during which the team began to finalize their ROV in preparation to begin developing the CAD model. Kyle took the lead by beginning to sketch the team's key decisions at the white board. As Kyle sketched, Paul and John began to ask elaborating questions— "How tall is the payload? So, then we need at least 6 inches, right? Did you guys take into account space for the cords?" The effect of the elaborating questions was such that, from that point forward, Kyle consistently labeled his sketch with dimensions to satisfy Paul and John until the entire design was developed. The meeting ended with the team delegating tasks related to developing the CAD model and custom parts.

These types of interactions happened frequently in my observations of The Yachtsmen. For example, during one meeting of The Yachtsmen, Paul began to make an argument about thruster placement in the team's design. Kyle noted that he was struggling to follow the argument and asked Paul to clarify his idea by sketching the idea on the white board in the room. As Paul drew his idea related to thruster placement, both he and Kyle began to talk through the idea, elaborating on the concept. Paul also elaborated on the idea by drawing multiple views of the concept. Later in the meeting, something similar happened, where Kyle spent time sketching ideas both for the presentation and to elaborate during the team's discussion.

I was tempted, at first, to categorize *elaborating questions* as a positive sign of effective teamwork in engineering. Working collaboratively to clarify ideas is, after all, an important learning outcome associated with team-based pedagogies such as those employed in ENGR 100. However, applying a critical lens to these questions during the analysis process made me rethink this and to instead consider these questions as potential indicators of influence on teams. I noticed a pattern that it was Kyle who frequently made overtures for clarification before the team proceeded. For example, during his individual interview, John reflected on the role of these clarifying questions in elevating ideas:

> So, I remember one time when we were walking from lecture to discussion. I think Paul was talking to me and maybe Seth. He made the idea of what if we lengthen the ROV, shorten it, and put the thrusters from on top of the payload to the side, and then we switched the bar around. So, we had some questions, some back and forth, getting him to fully explain the idea to us. Then after that, we were like okay yeah, that sounds great. Let's do that.

When John continued his description of Paul's process of convincing the team to pursue his idea of modifying the team's frame, he noted the different reactions from Kyle and Cam, noting the types of information that convinced him and the rest of the team:

> So, then Paul ran up to I think Kyle and Cam. He at that time didn't explain it as well. So, they were unsure, they didn't know what he meant by his idea. So, it took a little more time of explaining, in order for them to understand. I think we had to pull up the picture and say what we wanted to do. I think Paul just said like, "We're taking out the horizontal bar." They didn't know what that meant…

When I asked him to describe on the experience further, including what made the idea convincing to him, John continued:

> We were walking to class. There wasn't much else to do other than talk, but Paul seemed really animated about this. It was like he had a eureka moment. He was like, "Guys, why don't we just make thruster attachment much easier and make the ROV have a lot less drag, in one quick motion?" So, I was like, "Okay, that sounds interesting, can you explain the idea?" I was like, "Yeah, that makes a lot of sense." So, because it made a lot of sense to me, I wanted to make sure that I fully understood what he was talking about. So, then I asked him more questions, he told me his full idea. I think me liking his idea, caused me to ask more questions.

John's description of Paul's overtures to the team made me reconsider how elaborating questions might function in a team. If three members (i.e., Paul, John, and Seth) are satisfied by the explanation, but one member, Kyle, whose IDP formed the basis of The Yachtsmen's design, and another member, Cam, who controlled the team's CAD model still operated as potential gatekeepers, the elaborating questions might function as a process of influence. I began to ask who gets to pose these questions? Who bears the burden of proof, and how might this burden shape behaviors? What does this say about *who* is influential on a team, and *how* that influence is wielded? Even seemingly positive behaviors—opportunities to elaborate on and clarify ideas that might lead to team cohesion around those ideas—might be insidious in when they are used to wield power on teams to elevate particular ideas and marginalize other.

Still, elaborating questions did not always elevate ideas, and admittedly, I sometimes struggled at times to distinguish elaborating questions from attacking questions. For example, during a Team Mobula meeting, as the team worked to revise their design, the students engaged in a discussion of their priorities. The team turned to one of the broader goals—to win the team competition and began to frame their decisions around approaches to the competition, such as increasing speed or maneuverability. As the conversation progressed, Max began to ask the team to elaborate on ideas, particularly as they related to improving the team's chances of winning the competition. There were also discussions about the "fins" innovation, but it was not clear who was in support and who was opposed, or if this was even a neat distinction. At one point, Max posed a question: "What exactly are the fins helping?" Kevin answered quickly—"aesthetics"—and Chelsea added, "I actually think it might hurt", though she did not elaborate on that claim.

In the moment, Max's question appeared to spur an earnest discussion of the "fins" ideas, which came from Max's IDP. However, Max later expressed that he was hesitant to pursue the idea due, in part, to his inability to provide appropriate justification for the fins. Was Max's question an earnest attempt to facilitate thinking around the idea (i.e., an elaborating question)? Was the question meant to underscore the fact that they had no justification for the idea, thus moving the team to discard the idea (i.e., an attacking question)? Or was the question meant to undermine the idea without making overt antagonistic comments about it (i.e., a hedging question)? In the moment, and following the study, this was difficult to ascertain. Ultimately, the team discarded the idea.

Compare that exchange to the similar discussion during a meeting with Team Surge that I discussed earlier. In that team, Danish's support for the Trapezoid Frame was clear and explicit, and the opposition to the ideas was equally clear. Lauren, for example, stated her opposition explicitly during her interview. As the conversation became more contentious, Danish pressed the team to "name the negatives" of the Trapezoid Frame, asking the team to elaborate on their opposition. However, the tone and timbre of his question, in combination with his expressly stated support of the Trapezoid Frame, made it clear that his demand for support for other ideas was an attempt to elevate the Trapezoid Frame during the discussion. The words he used were similar to those used by Max, but Danish's clear intent distinguishes Max's question from Danish's attacking question.

The nature and use of questions I described in this section points to the normative supremacy of Eurocentric epistemologies in multiple ways that point to Proposition 1, Proposition 4, and Proposition 5. Thus far, I have offered evidence that the normative supremacy of Eurocentric epistemologies—most prominently seen in the need to adhere to scientific objectivity—did not appear to apply the same or equal pressure to all students in each team. As I described attacking questions, I noted that, while some students faced scrutiny and demands for support for their ideas, others operated without the same scrutiny. This finding points to equity issues in the ways that the need to adhere to scientific objectivity shape patterns of influence on teams. More importantly, the need to adhere to scientific objectivity by offering suitable support for ideas appeared, at times, to be weaponized to undermine others' ideas. This suggests that adherence to scientific objectivity is a mechanism for exerting influence, offering further support for Proposition 5.

Moreover, some demands for scientific objectivity were attempts to use the normative supremacy of scientific objectivity to undermine ideas the questioner did not support. In some ways, this undermines Proposition 1 and Proposition 4, which posit that adhering to scientific objectivity might be a way of gaining status and wielding influence. While Rehman's demands of Stephanie for support, as well as Matt and Chelsea's scrutiny of Addy's design, led Team Surge and Team Mobula away from Stephanie and Addy's designs, Rehman and Matt appeared to themselves operate without necessarily adhering to scientific objectivity, undermining the idea that it is adherence that leads to status and influence.

Conversely, elaborating questions did not function in much the same way as attacking questions—attacking questions appeared to undermine ideas while elaborating questions often clarified ideas. Thus, the consequences of attacking questions differed substantively from the consequences of elaborating questions. I suggest that elaborating questions still pointed to status and influence on the design teams. Elaborating questions, like attacking questions, still entailed demands for appropriate support, offering opportunities to evaluate the types of knowledge students drew on when elaborating and clarifying ideas for their teammates, as well as opportunities to assess the types of knowledge that might elevate or undermine ideas in each team. For example, though questions regarding Max's fins idea appeared to be earnest attempts to assess the idea. Yet at one point during their Preliminary Design Review, Max conceded, "I don't know much about the hydrodynamics or the physics behind it [i.e., the fins], but I do think the fins will help with stability." His inability to support the idea ultimately led the team to discard it, suggesting the need to adhere to scientific objectivity—offering "hydrodynamics or physics" support for the idea—might undermine some perspectives even when used earnestly during team discussions.

Finally, while elaborating questions appeared to be an indicator of good engineering work and good teamwork, I began to question the role of status characteristics (i.e., race/ethnicity and gender) in how elaborating questions functioned in teams (Proposition 5). As the project progressed, it became clear that asking questions, demanding clarification, and determining if the support a teammate offered is suitable required power and status on a team that was not necessarily afforded to all team members. Thus, elaborating questions might be earnest attempts to gather useful information, but not all elaborating questions are benign. As a result, I suggest the nature and use of elaborating questions might offer support for Proposition 5.

Manifestation 6: Rejection of Technical Knowledge

Manifestation 3 above revealed that some students relied on mathematics and science and other technical knowledge when their ideas were under threat of being discarded by teammates–suggesting their understanding of the normative supremacy of Eurocentric epistemologies. One might argue that the material benefits of whiteness were conferred on students due, in part, to their adherence and elevation of Eurocentric epistemologies in engineering. However, I documented moments when those benefits (e.g., the elevation of ideas and contributions) appeared to be revoked even when some students adhered to Eurocentric epistemologies in engineering.

For example, I observed Team Mobula during a meeting in which the team reviewed their presentation prior to the Detailed Design Review. When the team arrived at Addy's portion of the presentation during their practice presentation, I observed a familiar interaction between Addy and the rest of her team. Like the careful scrutiny her concept vessel had received, the team scrutinized her hydrostatic and hydrodynamic stability analyses. One student, Kevin, objected to Addy's conclusion:

> As the team began reviewing center calculations, Addy began to discuss the slide with the team to a slew of concerns from her teammates. Addy began to defend her calculations, drawing heavily on technical knowledge to defend her work. In particular, she expressed a concern that her calculations suggested the ROV would pitch and perhaps roll. To defend this assertion, she began to describe the relationship between the centers of gravity and buoyancy and how she developed the work on the slides. This, however, did not seem to convince the team. The team began to draw on a number of sources of information to push back on Addy' slide. For example, Kevin opened the course pack and Amy [instructor's] video from the start of the semester. Interestingly, (a) they never actually read from the course pack and (b) they never actually listened to the video. They were both opened as implicit support for Kevin's objections. Kevin began to tell Addy that her understanding of the relationship between the centers of gravity and buoyancy were not correct. He began gesturing with his hand, describing how forces act on the "vector of thrust" and how this would affect stability. The team agreed with Kevin based on his explanation and changed Addy's slide. Later, when Amy [instructor] asked if they had any concern about their design, Matt replied, "pitching," the concern Addy had raised multiple times before.

I returned to this incident later with both Addy and Kevin, noting that a number of their arguments used exceptionally technical language. Addy dismissed the role race might have played in the argument and indicated the team's objections were indicative of good, effective teamwork:

> I need someone else to give their opinion because I may not see it—like anything I did wrong. I trusted evaluations from any other person. I felt like the team was pretty friendly, and all the decisions were made for what they thought was best for the team.

Kevin, on the other hand, noted that he disagreed because he trusted his own knowledge above what his teammate had presented, saying:

> So it was our group meeting and I hadn't look over everyone's section yet, we'd all just kind of trusted each other. I was looking at the hydrostatic stability analysis, which is Addy's section, and what her diagram was suggesting was that our ROV, if it got tilted a little bit it would continue to roll and just completely turn upside down, which is a major issue because we were trying to get a very stable base to completely eliminate roll, but her analysis said that we were just going to roll upside down and then stay upside down. That was concerning to me, so I brought that up and she said that, "No, this is right," and I was basically like, "if this is right then there's a big issue with our design and we have to

> fix this." At the end, it turns out that the analysis was performed incorrectly because she was confused once or twice.

I was interested in Kevin's assertion that the analysis was performed incorrectly, in part, because the team proceeded to change the slide without any new calculations based solely on Kevin's explanation. His assertion that, "if this is right, then there's a big issue with our design," therefore it must be incorrect, was an assertion he successfully made to the team without the calculations and support Addy had provided to defend her concerns.

In my view, the degree to which Kevin or Addy was correct is immaterial; the point is that Kevin could assert correctness and use that assertion to modify Team Mobula's individual and team behaviors; this is an indication of his relative influence on the team. Members of Team Mobula "trusted" Kevin, and that trust was "implicit" because "we just kind of knew that he knew what he was doing" (Max's words). The implicit performance expectation meant not only that Kevin could exert influence without adhering to the normative supremacy of Eurocentric epistemologies, but that when Addy did adhere to Eurocentric epistemologies, her work was not trusted in the way Kevin's was.

In previous chapters, I noted that the adherence to Eurocentric epistemologies was at times superficial, but that adherence to Eurocentric epistemologies made students appear reasonable when they were opposing the epistemologies, ideas, and contributions of marginalized groups. Heavy scrutiny of ideas, particularly when those ideas fail to meet technical requirements, might appear reasonable on their own, but it was the absence of scrutiny for Kevin's that led me to believe that this was an insidious way that Eurocentric epistemologies contribute to marginalization in engineering.

Proposition 1, Proposition 2, Proposition 3 and Proposition 4 all presume that elevating technical engineering knowledge will result in higher status on teams, which in turn is reflected in increased action opportunities, more performance outputs, more positive performance evaluations, greater influence on teams. However, I found that the use of technical knowledge did not always result in students' ideas being elevated. Indeed, unequal scrutiny of ideas, and rejection of technical support for some ideas, suggests that the use of technical knowledge to elevate ideas (see: rhetorical shifts) was not effective for all students.

That this occurred to the only Black woman in the study might offer preliminary support for Proposition 5, which states that characteristics such as race and gender might shape varying patterns related to the degree to which adherence to Eurocentric epistemologies results in higher status on design teams. In Chapter 4, I discussed how Addy rejected the idea that race and racism had shaped her experience, and in my positionality statement I acknowledged that I would not likely have pointed to race or racism to explain such instances in my own experience. Still, the unequal scrutiny of Addy's work might point to the role that race plays in performance evaluations for engineering students.

Summary: The Role of Eurocentric Epistemologies in Teamwork

In this chapter, I focused on the role of six manifestations of Eurocentric epistemologies in shaping each focal team's approach to the design process. Across the teams, the normative supremacy of Eurocentric epistemologies appeared to shape the ideas students contributed both at the individual team and team levels. Moreover, the elevation of technical knowledge in engineering also shaped the ways some student wielded influence on teams via questions, as well as covert or overt attempts to elevate or undermine ideas in their teams.

As I interviewed the students on the focal teams, each student indicated that their experiences had been generally positive. When I asked students what had made their teams work so well, students repeatedly returned to the avoidance of conflicts through adherence to objectivity, systematic thinking, and rational decision making (all markers of Eurocentric thinking; see Brayboy, 2006; Harding, 2001). For example, John (The Yachtsmen) shared:

> I think one thing we all have in common is that we were very rational. So I think we were all pretty open-minded. None of us were really stubborn and getting a specific idea across. So, I think that impacted our design process. The fact that we ended up making decisions very quickly and we ended up with a very simple ROV. That we were just like all right, let's go, let's get in the water. I think maybe honestly, if there had been more conflict or if we had been more stubborn in our ideas, we might have ended up with an ROV that had more outlandish experimental qualities to it...It seems like everybody when they made an argument, they backed it up with their reasoning, which was based on something concrete. If we had any discussion of two different ideas, all ideas were heard for the most part. Then from there, the decision was made. There wasn't really any instances of people just buckling down. I want my idea, this is the best idea. You guys just don't understand. There was none of that, which based on the way they [i.e., instructors] talked about conflict resolution and whatnot. It seemed like there had been some pretty nasty conflicts in the past about ideas. So, I felt like we avoided all that.

Addy (Team Mobula) similarly connected her positive experiences to the team's reliance on technical knowledge rather than "random speculation" that might have led to more conflicts.

The idea that adherence to Eurocentric epistemologies helped, rather than hindered, collaboration and cohesion in the focal teams might seem like a positive outcome related to adherence to Eurocentric epistemologies. However, the equity issues I discussed in this chapter indicate that the resulting cohesion comes at a cost—students withdrawing ideas, teams failing to consider or acknowledge various contributions and perspectives, and the varying, unequal pressure Eurocentric epistemologies appear to exert on students in team-based learning settings.

Students in this study appeared to believe that their team's decision-making processes were rational, systematic, objective, often pointing to the tendency to offer good mathematic and scientific reasoning as behaviors supporting such beliefs. Moreover, students appeared to believe that the rational, systematic, objective qualities of their interactions were qualities that supported the team's cohesiveness. However, evidence presented in this chapter did not always support the idea that students were always rational, systematic, and objective, nor did the evidence suggest that the normative supremacy of Eurocentric epistemologies resulted in good teamwork, as students appeared to believe.

Instead, students appeared to understand how to wield particular sources of knowledge to exert influence and gain status on their teams. Rhetorical shifts, during which students *scientized* ideas in order to exert influence during design discussions, examples of such wielding of Eurocentric epistemic values. Conversely, moments during which students weaponized Eurocentric epistemic values (e.g., scientific objectivity) in order to undermine particular ideas are also examples of students wielding scientific objectivity to exert influence. While students appeared to believe that objectivity, rationality, and systematic thinking were earnest qualities that signaled good teamwork, I suggest the different ways that students wielded those qualities during the design process might be insidious mechanisms underlying processes of marginalization and exclusion in engineering.

Chapter 7: Centering Race* and Gender*

The fourth and final research questions in this study asks about the ways that the dominant epistemic culture of engineering manifest in ways that might marginalize students of color and women in team-based engineering design. In Chapter 2, I laid out various approaches to conceptualizing race and gender. I described (a) race/gender as a *variable*, (b) race/gender as *biology*, (b) race/gender as *socially constructed*, and (d) race/gender as *ideology*. Each of these conceptualizations of race and gender entail inherent affordances and limitations,

The propositions posited in Chapter 2 suggest elevating Eurocentric epistemologies will lead to higher status (i.e., Propositions 1 and 2), which I associated with opportunities to contribute ideas, as well as having those ideas elevated and enacted in design teams. Moreover, the propositions also indicate that adherence to Eurocentric epistemologies will result in more positive performance evaluations and greater influence (i.e., Propositions 3 and 4). Finally, Proposition 5 suggests characteristics such as race/ethnicity and gender might shape the degree to which adherence to Eurocentric epistemologies result in higher status, positive evaluations, and greater influence.

In this chapter, I continue to address the fourth research question by drawing on both quantitative and qualitative data separately, and in tandem (see Figure 4), to discuss what we can learn from each conceptualization of race and gender. I conclude by comparing the two sources of data and analysis in order to provide a richer description of the role of race, gender, and Eurocentric epistemologies in engineering teams.

Race and Gender as Variables

The first conceptualization of race and gender I described in Chapter 2 is perhaps the most often critiqued—race and gender as binary variables. Under this conceptualization, of race and gender, an individual is or is not a particular gender or race, and these are immutable categories encompassing broad, often problematic descriptions (i.e., man, woman, Black/African American, White, Latino/a) that presume people fit neatly into individual categories (Pawley, 2019). In my quantitative analyses, I pursued the conceptualization of race/ethnicity and gender as variables, in part, due to my inability to observe and interview students in the non-focal teams. I juxtapose the quantitative findings from the social networks strand of the study with the observational data from the critical ethnography to understand *if* and *how* the quantitative data might align with my descriptions of the focal teams. The social networks analysis allowed me to examine how students' contributions and enactments varied among all the design teams in the course, as well as the relationships between contributions and enactments in both the focal and non-focal teams.

Contribution and Enactment Patterns in Design Teams

I began with a descriptive analysis that examined students' patterns of interaction related to design ideas *within* teams by comparing the *idea contribution* networks to the *idea enactment* networks. In the idea contribution networks, directed ties represent perceptions that students were contributing ideas to their teams. In the enactment networks, ties represent perceptions that a particular student's ideas were used in the team's ROV design.

This examination of density and centralization metrics resulted in a preliminary understanding of patterns of influence on engineering teams (Table 12). Recall that density is the proportion of ties to total possible ties in a network and is a simple measure of team cohesion

(Borgatti, Everett, & Johnson, 2013). Higher density measures suggest students on a team perceived more egalitarian contributions or enactments. The density of the contribution network for Team D (Table 11) was 1.0, indicating that all the students on Team D believed all of their teammates were frequently contributing ideas. Centralization refers to the extent to which a team is dominated by a single, influential student and I used this measure to develop preliminary assessments of patterns of influence on the ENGR 100 design teams. Higher centralization scores suggest a team might be dominated by a single influential student. I also developed graphical representations of each team in order to examine the role of race/ethnicity and gender in shaping idea contributions and enactments. The variables for students' race/ethnicity were drawn from institutional records, but students reported their gender in their responses to the Beginning of Term survey.

All names in utilized in graphics are pseudonyms. Squares in each figure indicate students who described themselves as "female" and circles indicate students who indicated "male" status. Further, gray figures are students listed as "minority" as described by the institutional dataset, and white indicates non-minority students. While I draw on a subset of the focal and non-focal teams in this chapter, the contribution and enactment figures for all teams can be found in Appendix I.

Table 12. Network-Level Indicators of Shared Contributions and Influence

Pseudonyms	Contribution Network Density	Contribution Network Centralization	Enactment Network Density	Enactment Network Centralization
Team A	.90	.13	1.00	0.0
Team B	.90	.13	.70	.38
Team C	.70	.38	.50	.31
Team D	1.00	0.0	.67	.44
Team E	0.75	.31	.30	.56
Team F	.80	.25	.50	.63
Team G	.80	.25	.70	.38
Team H	.95	.06	.95	.06
Team I	.55	.25	.55	.25
Team Mobula	.85	.19	.75	.31
Team Surge	.90	.13	.75	.31
The Yachtsmen	.70	.38	.55	.56

Borgatti and colleagues (2013) noted that measures of team cohesion, like density and centralization, are best interpreted in comparative ways by comparing the same network at various times or comparing similar networks at once. For this reason, I compared density and centralization measures across the 12 teams to develop a sense of what constitutes a generally high or low density or centralization. The density metrics in the contribution networks were generally high, and the teams in general appeared to be relatively decentralized, suggesting many teams achieved a high degree of contributions early in the project. This might be the result of the course design—the instructors designed opportunities for students to develop their ideas (i.e., the Individual Design Proposal) and gave students class time to share those ideas in their teams. However, evidence from the qualitative strand might explain the relatively low density measures in some teams.

For example, I noted that Cam (a student on The Yachtsmen) did not participate in the early team discussions and was at times physically distant from the team members during early design conversations. As a result, I suspected that Cam was unlikely to be reported as a frequent contributor of ideas in his evaluations from his teammates, something reflected in the responses from The Yachtsmen (Figure 5). In a conversation with me, he indicated that his non-participation was due to extreme social discomfort with his team. Cam's experience underscores the idea that some students' experiences in the course reflected personal characteristics (e.g., introversion, self-efficacy) rather processes of marginalization related to their team's working dynamics. Thus, the appearance of inequity in each team may reflect other dynamics influencing the ideas teams considered and pursued.

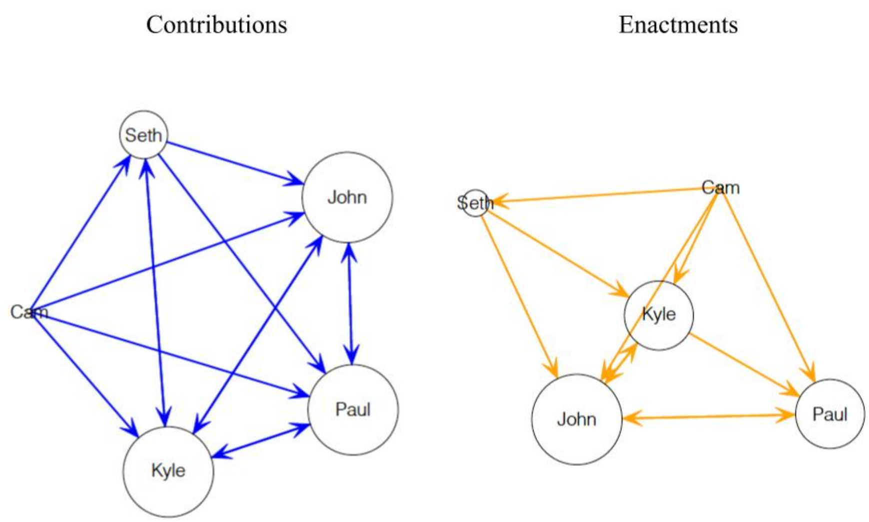


Figure 5. Comparison of Contribution and Enactment Networks for The Yachtsmen

Still, in general, the densities in the enactment networks were often lower than the densities in the contribution networks, and the centralization of enactment networks tended to be higher than the centralization of contribution networks, suggesting a general tendency of the teams to elevate the ideas of a particular student or students on the team. Again, these results should be read with caution. It is possible that the general decline between contributions and enactments reflect processes of inequity on teams, whereby some students' ideas were systematically undermined during the project. These findings, however, might also reflect normal team processes—it is not possible to use *all* of *everyone's* ideas on any given team, particularly if team members brought diverse ideas and perspectives.

Still, several teams emerged as potentially illustrative of the role that Whiteness and maleness play in shaping who is heard and enacted in design teams. For example, Team F, which consisted of three students identified as female and one student identified as "minority" in the institutional data appeared relatively egalitarian in their contributions of ideas to the team's design process (i.e., contribution network density = .80, contribution network centralization = .25). However, when students rated whose ideas were more frequently enacted on the team, the equality of contributions appeared to evaporate (enactment network density = .50, enactment network centralization = .63); White, male Will (pseudonym) appeared to be a central actor in the ideas that shaped the team's design (Figure 6).

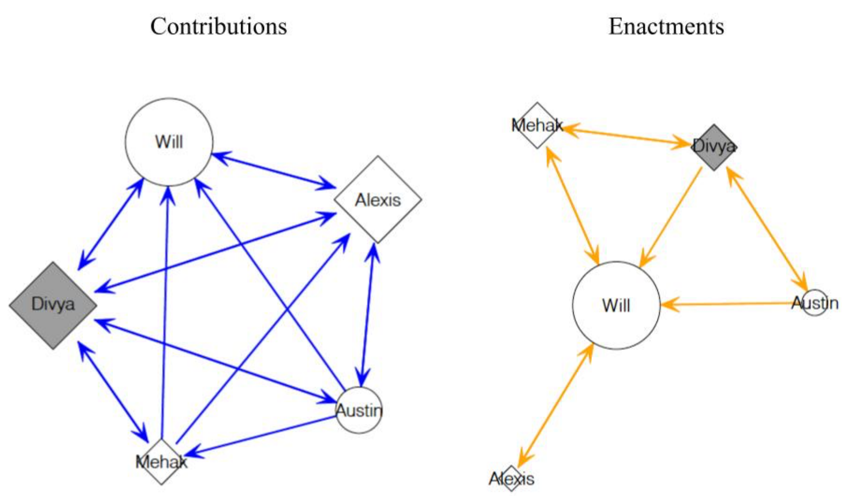


Figure 6. Comparison of Contribution and Enactment Networks for Team F

Similarly, Team E (Figure 7) displayed a pattern whereby male students' ideas appeared to be acknowledged and enacted more often than those of their female teammates (enactment network density = .30, enactment network centralization = .56), despite the degree to which students appeared to participate in idea contributions (i.e., contribution network density = .75, contribution network centralization = .31). Still, across both the contributions and enactment networks for Team E, the female students in the team appeared to be less influential actors.

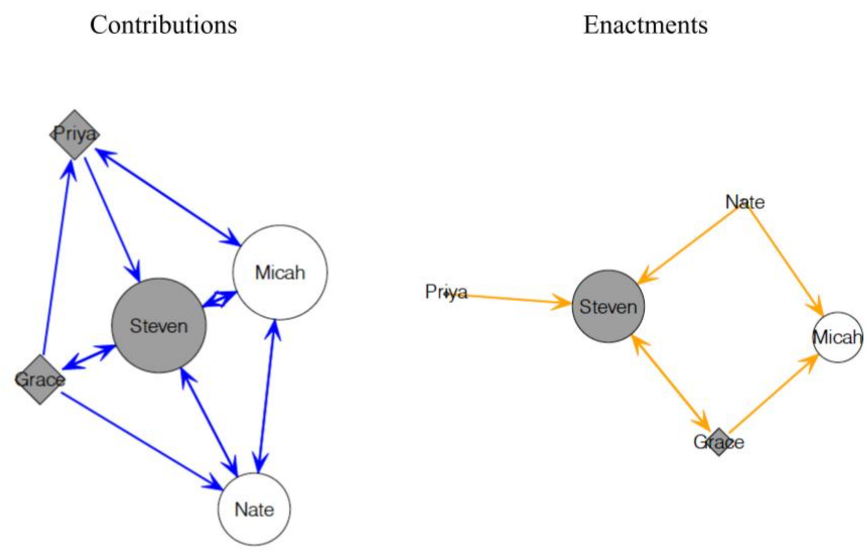


Figure 7. Comparison of Contribution and Enactment Networks for Team E.

For other teams patterns around race/ethnicity and gender did not appear to follow the presuppositions guiding this study. Team B, for example, which was described as a "female-dominated team" by its peer mentor, appeared to achieve frequent contributions of ideas from each team member (see Figure 8). However, when rating whose ideas were enacted on the team, Amy and Dwight (pseudonyms) appeared to have more of their ideas enacted. As I examined the various patterns by which women and minoritized students appeared to become influential or marginalized students on their teams, I turned to the peer mentor journals to try to understand how and why these different patterns came to pass. For example, Team B's peer mentor noted, "Right away it was obvious that Amy was the team leader," and though "everyone looked to [Amy] for validation and advice," Amy shared her leadership with Dwight. This dynamic on Team B appeared in their responses to survey items and is reflected in Figure 8.

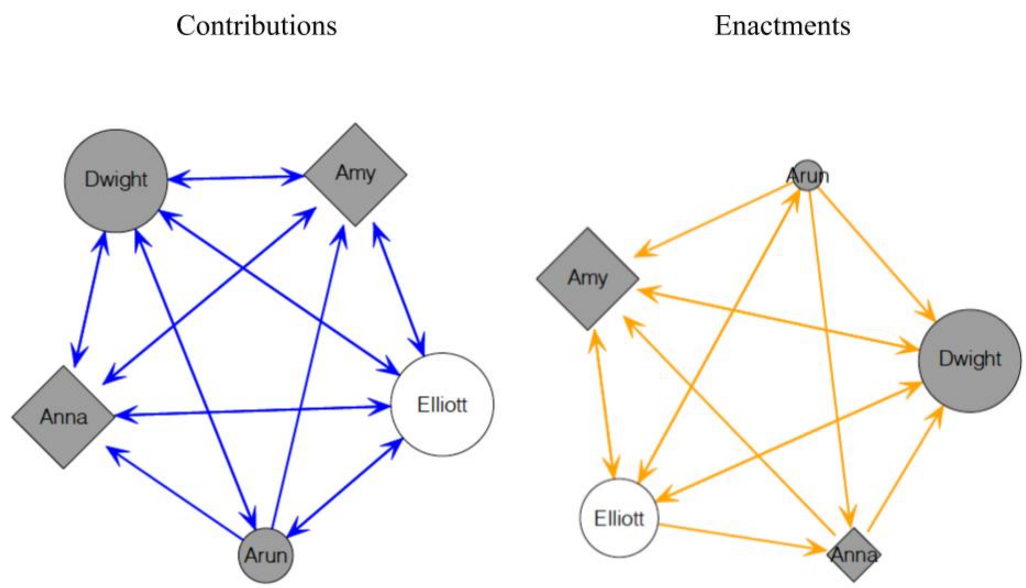


Figure 8. Comparison of Contribution and Enactment Networks for Team B.

The peer mentor for Team G (Figure 9) described a similar dynamic, where team member Arya was described as “dominating design discussions.” Though all members of the team appeared to share ideas (i.e., the contribution network), the social network surveys suggest that Arya became a central influential actor in the ideas that were eventually enacted. Still, I wish to note that the description of a woman of color engineer who contributed frequently as “dominating” is fraught with racialized and gendered undertones. Amy (Team B) on the other hand, who also appeared to be a frequent contributor, was described as a leader.

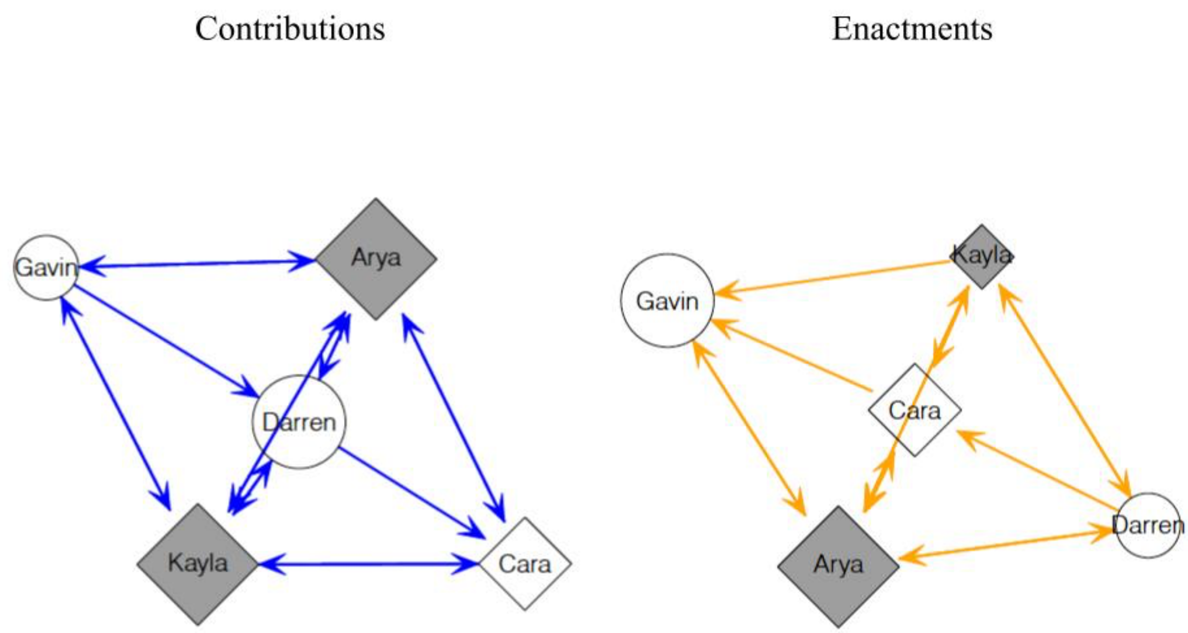


Figure 9. Comparison of Contribution and Enactment Networks for Team G.

The goal of the quantitative strand was to examine patterns both within and across teams related to race/ethnicity, gender, and process objectivity beliefs as measured by the ERB scales. For this, I turned to the multilayer exponential random graph models (i.e., multilayer ERGMs). My interest in the multilayer ERGM was understanding how exogenous covariates (i.e., race/ethnicity, gender, and process objectivity beliefs as measured by the ERB scales) shaped the ideas that were elevated, as well as how the idea contributions might be related to enactments across the teams. Findings from the multilayer ERGM are presented in Table 13 below.

Table 13. Multilayer ERGM

	Estimate (Log-Odds)	Standard Error
Idea Contributions		
Popularity: Asian American/Pacific Islander	.65	.69
Popularity: Underrepresented Minority	-.27	.66
Popularity: White	.60	1.16
Popularity: Female	-.84	.56
Popularity: ERB (Process Objectivity)	-.53	.14
Sociality: Asian American/Pacific Islander	.84	.99
Sociality: Underrepresented Minority	1.42	1.17
Sociality: White	.92	1.32
Sociality: Female	-.19	.61
Sociality: ERB (Process Objectivity)	-.32	.37
Homophily: Asian American/Pacific Islander	.00	1.25
Homophily: Underrepresented Minority	-3.00	2.21
Homophily: White	-.33	1.30
Homophily: Female	1.85	1.11
Similarity: ERB (Process Objectivity)	1.05*	.44
Idea Enactments		
Popularity: Asian American/Pacific Islander	-1.27*	.63
Popularity: Underrepresented Minority	-1.49*	.66
Popularity: White	-.48	.94
Popularity: Female	.33	.51
Popularity: ERB (Process Objectivity)	-.48	.27
Sociality: Asian American/Pacific Islander	.43	.73
Sociality: Underrepresented Minority	.77	.75
Sociality: White	1.26	.99
Sociality: Female	-.41	.49
Sociality: ERB (Process Objectivity)	.95***	.29
Homophily: Asian American/Pacific Islander	-.08	.96
Homophily: Underrepresented Minority	.56	2.16
Homophily: White	-1.02	1.04
Homophily: Female	-.62	.80
Similarity: ERB (Process Objectivity)	.35	.33
Cross-Layer Dependence Terms		
Reinforcement (Configuration E)	2.29***	.60
Unequal Contribution (Configuration H)	-.09	.50
Marginalization/Elevation (Configuration G)	.35	.76
Mutual Contribution (Configuration I)	-.01	1.61

Note: **p <.05, **p <.01, ***p <.001*

Several racial/ethnic categories were significantly related to students' ideas being enacted in their teams. Asian American/Pacific Islander students ($log\ odds = -1.27$) and underrepresented minority students ($log\ odds = -1.49$) were less likely to be seen as having their ideas enacted in their teams. This was despite the fact there were no statistical differences in idea contributions (i.e., layer 1). In the context of this ENGR 100 course, where instructors designed opportunities to share ideas into the course activities, the fact that underrepresented minority students and Asian American /Pacific Islander students appeared to have their ideas utilized less frequently might point to bias in how URM and AAPI students' ideas were assessed by their peers.

Notably, female status was not significant in either layer of the model. This was surprising given existing research that suggests women's ideas and contributions are likely to be undermined and marginalized in engineering contexts. However, again these results should be received with caution. In the qualitative strand, I documented patterns by which women strategically exerted influence over their teams. In the next sections I discuss potential explanations for these surprising findings.

Additionally, terms related to ERB responses (i.e., process objectivity scores) were statistically significant. On layer 1 (i.e., idea contributions), process objectivity similarity effects ($log\ odds = 1.05$) were statistically significant, indicating that perceptions of idea contributions were more likely between students with similar process objectivity scores. That is, students who reported similar views regarding the need to support and communicate ideas with math and science were more likely to share a tie. Moreover, process objectivity sociality effects ($log\ odds = .95$) were positive on layer 2 (i.e., idea enactment), indicating that students who indicated greater support for process objectivity reported that other students' ideas were utilized more frequently.

Finally, only one cross-layer dependence term, the reinforcement (Configuration E) term ($log\ odds = 2.29$), was significant in the model. This positive and statistically significant term suggests students who frequently contributed ideas were more likely to have those ideas enacted in their design teams. While this is not surprising, it makes the infrequent contributions of ideas (i.e., layer 1), which appears to be the result of elevating Eurocentric epistemologies, particularly problematic. If, as students articulated in the qualitative strand, students withheld or avoided advocating for ideas as a result of their inability to support or communicate those ideas with math and science concepts, these results suggest the hesitancy to offer or advocate for ideas might have larger implications over the course of the project. Moreover, as I discuss in Chapter 6, if the need to adhere to Eurocentric epistemologies was not felt by all students equally, these collective findings suggest the normative supremacy of Eurocentric epistemologies might impact the ideas engineering design teams choose to pursue.

Proposition 4 posits that engineering students who adhere to scientific objectivity might wield greater influence in their respective design teams. Findings from the quantitative strand, in combination with observations during the qualitative strand, call this proposition into question. For example, in the qualitative strand, I found that students in the focal teams who articulated that they were reluctant to share or advocate for their ideas were hesitant due, in part, to their belief that they did not have adequate or appropriate support for their ideas. The finding that students who reported greater support for process objectivity (via the ERB scales) were more likely to report other teammates as frequent contributors might be the result of their reluctance to offer and advocate for their own ideas during the design process. Moreover, the finding that idea enactments were reinforced by contributions (i.e., Configuration E in the multilayer ERGM) further undermines the idea that adherence to scientific objectivity necessarily results in greater influence. It appears that some students might have had *less* influence on their teams as a result of their adherence to Eurocentric epistemologies.

Conversely, Proposition 5 posits that race/ethnicity and gender might shape the degree to which adherence to Eurocentric epistemologies might inform status in teams. In this study, I suggest status is visible in various ways—the degree to which students contribute ideas, the degree to which their ideas are enacted or discarded, and *how* students elevated ideas or had their ideas undermined and discarded. Findings from the multilayer ERGM, in combination with findings from the qualitative strand, offer preliminary support for Proposition 5. The finding that students identified as underrepresented minority and AAPI were less likely to have their ideas enacted, despite no significant differences in idea contributions, might support this proposition. Using an illustration from one of the focal teams, I note that Addy's process objectivity scores were the highest on her team, and that aligns with my observation that Addy's contributions to the team were frequently in the form of technical arguments with her teammates. Yet, the qualitative findings reveal that Addy's reliance on technical knowledge did not mean her ideas avoided excessive scrutiny, and the quantitative findings indicate that her team members did not report that she was a frequent contributor.

Race and Gender as Socially Constructed

Masculine Norms in Engineering Teams

I also turned to my fieldnotes on the focal teams and peer mentor journals to search for patterns about the ways that some students became influential actors on their teams. In Chapter 2, I wrote the degree to which individuals adhere to social norms governing gendered behaviors reflects a conceptualization of gender as socially constructed. In the empirical literature, for example, Mahalik et al. (2003) measured adherence to masculine norms along a set of broad affective, behavioral, and cognitive dimensions of 12 factors (e.g., constraining emotional responses, exerting power over women, the desire to win, dominance).

Karpowitz and Mendelberg (2014) noted that "authority is the expectation of *influence*" and that "men and women tend to enter the room with different levels of authority." However, Karpowitz and Mendelberg also noted one can act in a way that enhances one's own authority and that "others can act in ways that enhance or detract from another's authority" (p. 18). During my observations at the start of the term, before students were in their design teams, I observed early lab sessions, during which students were allowed to work in arbitrarily assigned teams of two or three to complete the day's tasks. During both the pilot and study phase, I documented strong tendencies for women to pair with women, men to pair with men, and students of color to pair with students during the initial lab session. This pattern of gender homophily was so apparent—I documented this in all three sections across two semesters—that I began to wonder if the tendency would hold even after students were placed in assigned teams.

While six of the courses 12 teams, including one of the focal teams, consisted only of male students, the other six teams included at least two women because the course instructors explicitly prioritized pairing women on teams such that no single woman was "stranded" in a team of all men. In one of the focal teams (i.e., Team Surge), I documented moments during which the team divided tasks such that the two women on the team (i.e., Stephanie and Lauren) appeared to work together, yet separately, from the three men. This was accompanied by moments during which Stephanie appeared to work explicitly to "clear the floor" to ensure that Lauren's ideas were heard during meetings. During an informal interview, one instructor referred to this as "gender solidarity" in the design teams and suggested it was not altogether uncommon. Moreover, during their informal interview, both Lauren and Stephanie shared an awareness of the ways that gendered marginalization tends to manifest in teams and worked to circumvent those processes using various mechanisms (e.g., clearing the floor each other, preparing and clarifying ideas with each other before presenting them to the team).

Patterns by which women worked together to elevate each other's work appeared to develop in both the focal and non-focal teams, as documented by the peer mentors in their journals. Still, evidence of the role of masculine norms in shaping teams' design processes were apparent during my observations, interviews, and analysis of peer mentor journals. Importantly, describing these norms as "masculine" does not mean that they were embodied only by males/men in the teams. Existing research suggests that some of these behaviors, while more likely to be exhibited by men, are not uncommon amongst women. For example, Mahalik and colleagues (2003) described exerting power over women as a masculine norm in their scales. In this study, one peer mentor, while describing one woman who emerged as an influential actor in both the quantitative strand and the peer mentor's reflection, described that woman as "talking down to most of her teammates, especially [named another woman on her team]."

To be clear, it is not my intention to chastise the women I described in the previous paragraphs, nor is it my goal to make value judgements about the ways that students interacted in the non-focal teams. Indeed, I wish to avoid drawing inferences about teams that I did not observe; the data on these teams come from the peer mentors who were not guided by my theoretical framework or propositions while responding to the journal prompts that I provided. Still, one might argue that the woman in the previous paragraph appeared to embody masculine norms in her team, and it is possible that the woman embodied masculine norms precisely as a result of gendered marginalization over the course of the project. Indeed, her peer mentor described moments in which she argued with a White male student on her team and noted that those contentious disputes shaped their design process. Instead, the purpose of this section is to provide potential explanations for *how* and *why* some teams appeared to avoid the expected patterns of gendered marginalization in engineering. That is, the woman I described in the previous paragraphs may have engaged in teamwork in particular ways precisely as a result of gendered marginalization. Just as in Chapter 6, where I argue that some students adhered to dominant epistemologies in engineering precisely in moments during which their ideas were being discredited, it is possible that adherence to masculine norms was a mechanism by which some women in the teams exerted influence that would otherwise not be difficult to exert, if not altogether impossible.

My interviews with students in the focal teams, both men and women revealed that students were aware that some team arguments and debates were a direct result of perceived gendered marginalization. The interview data thus aligned with what I observed. For example, over the course of several meetings with Team Surge, I noticed a pattern of interruption that persisted throughout the meetings. I documented the ways that individuals appeared to respond to interruptions, including my perception that the interruptions often happened to women on the team. Specifically, I noticed times in which Lauren and Stephanie (Team Surge) would "clear the floor", either for themselves or each other, in order to be heard:

> On occasion individuals interrupt conversation in order to redirect the conversation, particularly by asking permission for the floor. My sense is that the women on the team do this the most often. For example, just as in the meeting in my office, I notice Lauren ask for permission—"Wait. Can I say something?"—before she starts to sketch the frame at the white board. I began to think that this tactic from Lauren and Stephanie is not necessarily asking for the floor but ensuring that the other team members are actually listening to them when they speak. This pattern of asking for permission to speak also happened in my office from Stephanie. On the other hand, Rehman is the person most likely to "throw ideas against the wall" without permission, but my sense is also that the group is least likely to take his ideas on and "workshop" them in the same way they do the others.

As the term went on, the pattern of interruptions on Team Surge became such a problem that students eventually began to lay bare their frustrations during team meetings. For example, during one team meeting, I documented a rather terse exchange between two students:

> Stephanie began explaining her design decision about the placement of the joints. As Stephanie was speaking, Ryan again interrupted to describe his and Rehman's argument. Stephanie became exceptionally frustrated by the interruption, and I heard her sarcastically say, "I guess I won't get to finish a sentence."

I returned to these instances during the Design Experience Interviews, and both the men and women on the teams agreed that the culture of interruption might have been perceived as indicative of sexism in the team. For example, Ryan noted:

> I think Stephanie might have saw it [i.e., interruptions] as me trying to talk over her because she is a woman in engineering, and historically they might not be treated in the same regard. I think she was very aware of that, whereas I wasn't aware. It wasn't something I was trying to do. There were a couple of times when [the men] were talking, and she would say, "Don't talk over me."…It's something they're (i.e., women) conscious of, and therefore you want to be conscious of it.

As Ryan noted, women in the study were aware of the ways that sexism appeared in overt ways in engineering. For example, in her interview Lauren described conversations in which she directly told her male peers that she did not feel heard, and that she viewed their behaviors as counterproductive. Other men on team were also aware of this. Rehman similarly recalled moments during which Stephanie "made comments about women in engineering stuff" and acknowledged the "gender divide" in task allocation (i.e., where Stephanie and Lauren worked separately from Danish, Rehman, and Ryan) during some working meetings. Members of Team Surge understood the mechanisms of gendered marginalization and, at times, their contentious discussions were a response to perceived gendered marginalization in the team.

Similarly, in Team Mobula, Chelsea recognized overt patterns of gendered marginalization. Chelsea spoke about how frequently she had been "completely shut down" in her other engineering classes, though she said that she never felt that way in Team Mobula and that challenges to her ideas were not on the basis of her status as a woman in engineering. Still, after several incidents in which her teammate Matt changed her work without her knowledge or input, Chelsea acknowledged that she viewed the incidents as typical of the experiences of women in engineering but stopped short of calling those behaviors sexist. While Matt suggested he did not believe the incidents upset Chelsea, and he acknowledge that he had not discussed the incident further with Chelsea, Chelsea described frustration at the incidents.

Gender* in an All-Male Team

Conceptualizing gender as the degree to which individuals adhere to masculine norms is fruitful because it offers an opportunity to study gender where there is no apparent diversity (i.e., if gender is understood as a binary variable), such as an all-male engineering design team. I entered this space conceptualizing gender as a complex interplay of biological sex (e.g., male), identity (e.g., man), and expression and performance (e.g., masculine) (Nicolazzo, 2015). I wondered how, for example, gender might appear on an all-White-male team like The Yachtsmen.

During my first observations of The Yachtsmen, I noticed that John, who later identified himself as bisexual, wore painted fingernails in class, and I wondered how his gender *expression* might be perceived by his teammates. While it was not clear the degree to which his sexual identity was known to his teammates, one teammate, Paul, spoke to me about the sense he made of John's nails and behaviors in the team. For example, Paul discussed how he had connected with another student, Kyle, in part because they had the "same upbringing." Paul and Kyle bonded over the fact that they were both high school athletes from rural backgrounds. Paul noted that John, on the other hand, was "a little different in some aspects," that he was "taken aback" by the painted nails, and that he had "never experienced a person" like John before. Though both John and Paul said they did not believe John's gender expression had played a role in their interactions and team experiences, Paul's recognition and response to John's failure to adhere to masculine norms was an indication that future research should examine the role of gender more broadly than binary, immutable categories. Taken collectively, these observations suggest that understanding how adherence to masculine norms – whether by students who identified as men or women – affects design team interactions and processes might be an important direction for future research.

Gender as a Silent Factor in Engineering Teams

Beyond the explicit manifestations of gendered marginalization, gender shaped the design process in ways that were not always visible and that emerged only on reflection with students in the focal teams. For example, Matt, a White male member of Team Mobula, was described by team members as a "*de facto* team leader." When I asked members of Team Mobula how this came to pass, one member offered that it was due to "subtle factors," such as his friendliness and the fact that he "seemed like he knew what he was doing." This description of a teammate occurred twice during the Design Experience Interviews with members of Team Mobula. Kevin, for example, was given almost sole responsibility for a major portion of the project. Max offered that the team trusted Kevin, that the trust was "implicit," because "we just kind of knew that he knew what he was doing." Max acknowledged that his description was a difficult to explain and "psychological," alluding to implicit feelings of competence he and other teammates held for Kevin during the project that guided their trust and decision making.

That Matt and Kevin assumed leadership roles and action opportunities on their teams due, in part, to implicit ascriptions of competence by their teammates is consistent with the propositions of status characteristics theory. As I discussed in Chapter 2, SCT posits that some diffuse status characteristics (e.g., race, gender) are associated with performance expectations. In engineering, where White and male are associated with competence, this research suggests that these characteristics might also have translated into increased action opportunities, as well as influence resulting from those action opportunities, in Team Mobula's design process.

The salience of gender appeared in other aspects of the design process in ways that might have eluded outside observers. Both Lauren and Stephanie offered that they did not bring any engineering skills to Team Surge. However, upon reflection, Stephanie acknowledged that she had played down her experiences due to her lack of confidence. Stephanie also reflected on the role gender might have played in her lack of confidence:

> Something that I've been thinking about…The idea that when I think I don't have engineering skills, I think that I might have the same amount of engineering skills as a lot of the other people on our team…I've been thinking about this a lot a lot with respect to Engineering 100 and 101. I took two years of CS in high school. I feel no confidence in my CS skills. I took as much CS as probably anybody else on our team…Even coming in, I think that I am much more likely to evaluate my engineering technical skills as lower than other people with the same technical skills.
>
> I don't know. I think something that sticks out to me generally at Michigan Engineering is we self-select into (Introductory Programming) or (Honors Programming) depending on what you perceive is your own level of CS background…I never ever would have done (Honors). I wouldn't have but there are people that I know who did it who are just boys…Also, there were a lot more girls in my 101 class. I think they don't pick 151…Yeah. I think about that a lot. I literally don't know a single girl who took 151. My 101 class was definitely at least 50% women or very close to even.

The fact that Stephanie came to believe that she entered the engineering space with equal experience to her male counterparts but less confidence, and the relationship Stephanie perceived between her lack of confidence and gender, is also related to how Team Surge engaged in the design process, particularly as they relate to the behavioral sequences posited by SCT. Again, SCT posits that implicit beliefs about competence inform action opportunities and influence in teams. Early in the project, Team Surge began to delegate tasks based, in part on perceived and stated competence—who is good at what? That Stephanie undervalued her skills meant that she was precluded from being delegated particular action opportunities. The coding on the control box, for example, was quickly assigned to Danish.

Conversely, whereas Stephanie understated her competence and related her minimization to the role of gender, the opposite, wherein male counterparts overstate their skills, also occurred in this research. Seth, of The Yachtsmen, for example, spoke about how he had overstated his coding skills in response to his realization that other teammates had experience with other portions of the project. Seth noted how “it seemed like everybody had experience with the lab equipment before,” and he understood that the team was seizing roles by “finding a part of the project that they were comfortable with.” Unlike Stephanie who understated her skills, Seth overstated his skills:

> The only thing is I feel like I knew going into the project that my coding skills weren't going to be a big part of this project because most of it wasn't coding…Even with the coding, I knew I wasn't going to be the most experienced coder on the team either, because John and Paul had both taken the programming class ahead of me last semester, so I knew they were also very solid programmers and they would have helped contribute to that too. So, it wasn't like the programing skills were what were going to set me apart in the team.

Though the team never coded their control box, it was understood that Seth would play some part in the coding due, in part, to his stated skills. While Seth did not relate his decision to overstate his skills to gender the way Stephanie related her understatement to her status as a woman in engineering, their different approaches to positioning themselves for action opportunities on their teams is noteworthy as it supports the idea that gendered power appears beyond overt interactions between men and women.

Taken together, these findings indicate that there are visible and invisible ways in which gender and gender power shaped teamwork in the focal design teams. The visible ways include men talking over or "shutting down" women); the invisible ways included women minimizing their skills while men overstated their skills. These gendered ways of presenting oneself and interacting in teams influence task allocation and ideation in student design teams. Moreover, students are aware of and, at times, responsive to, known processes of marginalization.

While these findings do not point to the role of Eurocentric epistemologies in engineering directly, they do offer support for the idea that diffuse status characteristics, such as gender, shape the experiences of engineering students in team-based design settings. For example, I documented contentious moments during which both men and women acknowledged that patterns of behaviors (e.g., interruptions, unilateral decision-making) were consistent with known sexist behaviors in engineering. Even the team for which all students were male (i.e., The Yachtsmen) pointed to the role of gender norms in their interpersonal experiences even if they could not describe ways that those norms shaped the design process explicitly.

Race in Engineering Teams

Research in engineering education and higher education often relies on conceptualizations of race as immutable categories (e.g., Black, White, Asian) (see Pawley, 2019). Several students in the focal teams spoke about their identities in ways that challenged my use of a single variable to capture race in the quantitative strand. For example, Rehman, who described himself at times as "half Indian," also suggested he shared a racial/ethnic identity with Danish, and that they had spoken about it during the project. Danish, however, never described himself as Indian, but regularly described himself as "Asian," particularly during the Design

Experience Interview. I thus identify Danish solely as Asian, recognizing this may not capture the whole of his identity or his experience in engineering.

One student in the study alluded to the ways that our naming of race and racial categories might not reflect lived experiences in engineering. When I asked if he believed his racial identity shaped his experiences in engineering, including the way he is perceived in engineering broadly, he offered that he was conscious of race when trying to navigate the professional world. Moreover, he added that though he thought that sharing that he was Asian in applications might not mean he'd hurt his chances of being hired, his status as "minority" felt tenuous:

> It's almost like we turned into the opposite of a minority, I feel like in the engineering realm at least. Like it used to be if you're Asian, if you're a woman it could be easier for you to get a role...or not *easier* but you might be seen as more diverse if the company decides to move forward with you. Now it's like the opposite. There's so many Asians in the [computer science] category with company jobs and stuff like that, and engineering roles at schools. A lot of schools will, I feel, give you less consideration because you're just not standing out amongst those Asians who are also interested in engineering.

This comment was important in the context of this study for several reasons. First, in the quantitative strand, which utilized institutional data for race/ethnicity variables, Asian students were categorized as *minority*, but Asian students were not listed as *underrepresented minority* students in the data. In this study, I used the variable distinguishing *underrepresented minority* students, and an additional variable distinguishing Asian students in the sample. However, this student's reflection suggests that the Asian category (i.e., *race as a variable*) does no capture his experiences living at the intersections of multiple identities in engineering.

Additionally, this is meaningful since some institutional efforts, particularly in engineering, are geared at supporting underrepresent students. It is not uncommon, for example, that studies regarding race in engineering call out disparities for underrepresented students. This student's comments suggest that Asian students operate in a racial liminal space—certainly not the White majority, but also, at least in engineering, not quite a "minority."

Such comments highlight the nature of race as a socially construct. A comment that when "there's so many Asian" it is "hard to stand out" suggests an awareness of structural diversity. Similarly, this same students' statement that Asian is "almost like…the opposite of a minority" further suggests a set of social experiences he associated with "being a minority", including the experience of applying for employment and admission to college. That some of his experiences aligned with his perceptions of "being a minority," while others diverged underscores the problematic nature of categorizing students by race in quantitative analyses.

With such caveats and complications in mind, I used race as a marker of identity in this study to understand how it shaped team-based design processes. Beyond where my own analysis and interpretations led me, it was important that I spoke with students about their perceptions and experiences both as engineers broadly, and as participants in their respective teams. At the end of the ENGR 100 experience, I asked students in the focal teams to reflect on the role of race and gender in engineering, as well as in their interactions with their teammates over the course of the project.

While both men and women in the three focal teams were prepared to discuss the important role that gender had in shaping their team's interactions, few saw race as a contributing factor in their experiences. Addy, a Black woman engineering student on Team Mobula, rejected the idea that race had shaped her experience, arguing that her teammates had treated her "like any of the regular teammates." However, during my observations, I documented times in which I perceived Addy was being excluded, either implicitly or explicitly, from the team's work. Most prominently, for example, was the fact that Team Mobula scheduled a meeting in Addy's absence during which the team made important design decisions. I wrote about this meeting in my fieldnotes:

> At the start of the meeting, after a short discussion, Chelsea and Matt (announced by Matt) decided the team must decide on a design during the meeting. Max immediately expressed concern about this since Addy is not present. Max asked the team to find a way to include Addy, perhaps by having her call in. Matt said he assumes she cannot call in since she never offered, and that it would be too much a hassle. Addy, then, will play no role in the team's biggest decisions.

Addy's absence from this particular meeting became an important factor in the team's design process. During the meeting, Team Mobula began discussing many the key design decisions (e.g., a re-design of their frame, degrees of freedom, thruster placement) and at the conclusion of the meeting, Matt noted that the team had almost completely changed their design since the Preliminary Design Review. The team thus worked to develop a strategy of delegating tasks and informing Addy of their decisions. I asked each member of Team Mobula about this meeting and how, if at all, they had involved Addy in their decisions after the meeting. Addy noted that she did not push back on any of Team Mobula's decisions because her understanding of the meeting was that "the four of them had agreed," and that if the majority agreed then it must have been the best decision for the team.

However, Kevin noted that the team had indeed *not* been in agreement about key decisions. In particular, he discussed his position about the degrees of freedom, noted that he and Addy had had similar degrees of freedom they wanted in their individual designs, but with no support during the meeting, he simply relented to the others on the team:

> Addy wasn't at our meeting and Max, I think he was probably going to side with Chelsea, although it was only a little bit. It was mostly neutral so it was basically me arguing my own design versus Chelsea arguing her own design. One of us had to give eventually and I didn't want to [pause] ... As long as I got to build and drive it around a little bit, even if it wasn't at the competition, I didn't really mind giving up my idea to build someone else's because I know that when you suggest an idea and can invest time in it, it really hurts to

> just be outvoted and for the team just to go a different direction when you've already invested in one idea…So I just decided to drop it.

Although the students believed Addy's exclusion from the team meeting had not played a large role in the team's work, at least some design decisions might have changed if Addy had been present during this meeting. Moreover, in addition to making important design decisions, Team Mobula also began assigning tasks during this meeting. This was the first time in which I observed influential team members shaping the behavioral sequences posited by status characteristics theory. In Addy's absence, the team began to delegate tasks (i.e., action opportunities) in the project, with Matt assigning himself the critical CAD modeling task and assigning Addy tasks that he noted were "the easiest way to do something if you were not here."

While Addy's exclusion from the discussion is not evidence that she was excluded *because* she is Black, a woman, or a Black woman, her exclusion from this meeting was part of a pattern that some of her teammates acknowledged. For example, one of Addy's teammates, Max, reflecting on this and other incidents that occurred during the project, acknowledged they "didn't do a good job of bringing her into discussions" and recognized that some experiences may have left her "feeling like she didn't really belong."

Other students of color in the focal teams, like Addy, similarly dismissed the role of race in their respective teams but spoke about their racialized selves in the context of engineering more broadly. For example, Rehman, did not believe his racial identity had informed his experiences on his team, and that, in his view, this was also true of his experience in engineering more broadly:

> I think, for me, I'm half Indian and I don't think that's ever once affected me in a setting like this. Maybe someone will make a good joke when I'm with my friends or something like that. It's not a big deal. I don't think it's ever affected me in a group setting, like an academic setting ever. The same holds true for here. I don't think I ever felt anything like that. Danish – we talked about – it could be a different story for him, I know he's stronger

in his ethnicity and stuff like that... From what he's told me, I don't think that he felt anything like that. There was that one joke that was funny. That was the only time I feel like it even got brought up.

The joke Rehman is referring to occurred during a meeting in which Team Yaw practiced their Detailed Design Review. After their first run of the presentation, the team agreed that they had spent too much time on the introduction slide introducing themselves, which caused them to run over their allotted time. One member, Ryan, the only White male on the team, suggested they skip the slide altogether to save time. Danish, however, disagreed and jokingly expressed concern that, due to his shared racial identity with Rehman, as well as Lauren and Stephanie's shared gender identities, it was important that team clearly establish each member:

Danish: "Ryan, you're the only person people will be able to pick out."
Ryan was initially confused: "What? How?"
Danish: Well I could be Danish or Rehman…
The team began to laugh as they all realized the joke.
Danish continued: …and she could be Lauren or Stephanie.
Ryan acquiesced and agreed that everyone should introduce themselves to be clear.

During the member checking process, I wrote that this moment was an indication that race and gender were at least "somewhat salient" to the members of the team. However, both Danish and Rehman pushed back on this assessment, with Rehman saying he "never even thought about race" and Danish saying the episode was more about receiving adequate credit than it was concern about race and racism. Both Danish and Rehman spoke to me about *my* perspective on the role race had played on their teams, with Rehman indicating he was open to reconsidering "if there was a clear something going on that divided between the races." After the comment, I reflected on my own positionality. As I described in previous chapters, I did not anticipate students would center race and racism in their reflections in part because I did not center race and racism in my descriptions of my first-year engineering experiences. It was not until years later, after a pattern had developed, that I began to develop a language to describe my experiences that led me to this research. Rehman's assertion that he might reconsider if "there was a clear something going on" is not altogether different than what I might have said during my first year in undergraduate engineering.

Just as I focused on ways that gender (i.e., adherence to masculine norms) and race might shape dynamics on an all-male team, I also asked members of The Yachtsmen, the all-White focal team, to discuss the role social identities, including race and gender, played in their design process and teamwork over the course of the project. Several students discussed how their racial and gender homogeneity became apparent to them as they completed an exercise in the online Tandem tool. Kyle offered that the members of The Yachtsmen were all "pretty like-minded" with "similar experiences." Cam similarly offered that they "were all just so alike", and that an instructor had joked that The Yachtsmen were "the least diverse group out of all the ones in the class."

Still, reflections from The Yachtsmen suggest that, even in the absence of structural racial and gender diversity, students seemed to be aware of race and gender in their teams, even if passively so. For example, Ryan of Team Surge joked that he had noticed that no team in the class had any less than two women. This was true, and that was a purposeful decision by the course instructors—although the instructors did not share this during the team formation process. Still, it did not go unnoticed by students in the room. Like Cam's seeming awareness of his team's lack of diversity, Ryan was similarly aware of the teams' racial/ethnic and gender compositions.

Race, Gender, and Eurocentric Epistemologies

To connect these findings on the role of race, gender and Eurocentric epistemologies, I begin by addressing race/ethnicity and gender in the quantitative strand. As I have noted, a common methodological approach used to examine racial/ethnic and gender differences in quantitative research—and one that I have taken in my own work—involves comparing group (e.g., racial/ethnic or gender categories) means on latent constructs (e.g., multiple indicator and multiple causes models in structural equation modeling, “dummy” variables in linear regression models). If our models detect statistically significant differences in, for example, process objectivity scores between male and female students, we might conclude that there is some aspect of sex or gender that leads women to have different engineering-related beliefs than their male counterparts on average.

In this study, I did not pursue such an approach or test for group mean differences in part because of what I learned observing teams and analyzing qualitative data. First, it appeared that some students adhered to Eurocentric epistemologies precisely to avoid the ways that Eurocentric epistemologies might marginalize their ideas. For example, Lauren’s meticulous preparation appeared to work to circumvent the role of dominant, Eurocentric epistemologies.

Second, at best, the epistemological belief scales assessed students’ beliefs about engineering knowledge in the abstract and my concerns about this rose as I conducted my study. During individual interviews with students in the focal teams, I asked students to return to the epistemological beliefs items they responded to at the start of the term. In discussing their ENGR 100 experiences, some acknowledged differences between how they responded at the start of the term (i.e., in the abstract) and how they behaved during the project (e.g., “I know I probably said X at the start of the term, but I often did *not* X in my team”). For example, Ryan spoke about how his views of the role of technical knowledge in engineering design had changed particularly in the context of the ENGR 100 project:

> I think knowing me, I probably started off this semester saying, "100% true. I strongly agree with that. That has to have math and science backed up." And now looking back at

> that, that's really interesting because I feel like I've been talking that a lot of our options and choices were based on intuition and how we feel…Obviously if it was like a more serious project, I think that more math, and science, and actual analysis would be a good thing to have, but I think for our goals and just the laying down foundations of design, maybe it doesn't have to rely on the technical aspect as much as drawing from what you've seen. And then from there, extrapolating, just using I guess your intuitive senses to try to make a new design based off of that. But I think that is interesting because that's definitely changed for me.

By the end of the term, some students outright rejected their responses from the start of the term. For example, Cam, who had the highest process objectivity score on The Yachtsmen team offered that he had learned the importance of the social nature of the sociotechnical design process as a result of his experiences in ENGR 100:

> So, I guess now I'd say based on what I've experienced this term, it's... There's more of a human factor that's involved. You can't just rely on numbers and observation just to support your claims. You can't just seem like a robot whenever you try to do something, especially when you're interacting with others. And I guess I put less emphasis on the technical aspect of engineering and trying to emphasize more about how to communicate with others, how to present your ideas, how to come off as more human because that's what engineers are, I guess.

These comments suggest that the ways that students experienced the engineering design process shaped the degree to which they elevated Eurocentric epistemologies in engineering. As a result of their design team experiences, Cam and Ryan learned put less emphasis on technical knowledge in engineering. Cam, for example, noted that “you can’t just rely on numbers and observation to support your claims,” and that he should “put less emphasis on the technical aspect of engineering” in favor of learning to communicate with others. Importantly, Ryan appeared to learn to put less emphasis on technical knowledge precisely because he had the space and opportunity to use his prior experiences and intuition during the design process.

Another reason I did not test for group mean differences was because some students appeared to elevate Eurocentric epistemologies in response to their experiences of who is perceived as credible in engineering, how one becomes credible, and how one loses credibility. As I analyzed responses that expressed support for Eurocentric epistemologies in engineering, there was a recurring pattern in students' discussions using math and science to convince others, win arguments, and elevate ideas. Danish (Team Surge), for example, elevated Eurocentric epistemologies because he understood that ideas supported by math and science were "less easily argued against" because they are, in his view, "closer to right or wrong." Lauren (Team Surge) said ideas needed "quantifiable backing," otherwise you "can't…expect people to agree with what you're saying."

I have repeatedly referenced Pawley's (2019) critique of utilizing race/gender as a variable in studies exploring the role of race/ethnicity and gender in engineering education because such an approach essentializes a diverse set of people, their experiences, and their social contexts. In this study, findings about race/ethnicity and gender did not necessarily align with the theoretical perspectives guiding the study. However, these findings should be understood with caution. Though it appears (i.e., in the quantitative strand) that there were not significant differences between women and men in the frequency of contributions and enactments, evidence in the qualitative strand suggested that women had to employ strategies to be heard on their teams equally (e.g., Lauren's meticulous preparation). Even then, gendered marginalization was still a factor (e.g., Matt's changing Addy and Chelsea's work without their knowledge).

Simply put, social context matters.

In the quantitative strand, I found no significant differences in the contribution networks by race/ethnicity and gender and no significant differences by gender in enactment networks. I also found that process objectivity beliefs were positively related to perceptions of idea enactments (i.e., layer 2). However, the social context I documented during observations might explain these findings. Students appeared to make strategic decisions around *when* to communicate and advocate for ideas and, importantly, *how* to communicate and advocate for their ideas. For example, when Danish understood that his ideas were “being argued against,” he strategically changed his communication strategy, elevating math and science concepts to convince his team to pursue his ideas. Here, the reading of the social context—perceived threat to ideas—informed *how* ideas were communicated and advocated for to the team.

Others might have expressed support for Eurocentric epistemologies, but they navigated the design process feeling free to use intuition, prior experiences, and other sources of knowledge to describe and elevate their ideas. Here, the social context was more opaque. Whereas some students were able to elevate ideas using their intuition and prior experiences, another student articulated developing and communicating her ideas more thoroughly in an effort to ensure she would be heard. This finding appeared to undermine the propositions guiding the study. Namely, that some students were able to elevate their ideas despite not communicating those ideas using technical knowledge and adhering to scientific objectivity undermines the idea that it is the pure, elegant support of math and science that results in the elevation of some ideas over others. Instead, it appears *some* students are able to proceed without the technical support required of others.

Even further, is possible that some students were not perceived as frequent contributors precisely because they withheld or did not advocate for ideas in light of their elevation of Eurocentric epistemologies. These students elevated Eurocentric epistemologies so much so that their need to adhere to scientific objectivity by communicating their ideas using appropriate math and science concepts appeared to make them more reluctant to contribute ideas. This, in turn, made their ideas less likely to be enacted. This finding also undermines the propositions that suggest elevating Eurocentric epistemologies will lead to higher status, and for some students, elevating Eurocentric epistemologies might have had the opposite effect.

Similarly, as I read the peer mentor journals, I documented peer mentors' reflections on their team's decision-making processes. Just as I documented that reliance on the normative supremacy of Eurocentric epistemologies did not appear to elevate particular students' ideas during my observations of the three focal teams, another peer mentor noted that the two women on her team "appeared to have the most reasoning for why certain aspects were picked and how the design would impact performance," they did not seem to contribute as much to the overall design. While the peer mentor did not offer an explanation for how or why this occurred, the reflection again pointed to a pattern by which explanation and *reasoning* did not always result in ideas being elevated on first-year student teams, offering further support for Proposition 5.

Summary

In this chapter, I synthesized the quantitative and qualitative strands in order to discuss the role of race/ethnicity, gender, and Eurocentric epistemologies in engineering design processes. Overall, I found that race/ethnicity and gender appeared to shape the ways the design process in teams in ways captured in both the quantitative and qualitative strands. Moreover, the ways that race/ethnicity and gender shaped students' experiences broadly, and the design process specifically, were clearer when race and gender were viewed through the various conceptualizations outlined in Chapter 2.

When viewed as variables in the quantitative strand, gender did not appear to distinguish the degree to which students contributed ideas, nor did gender separate those students whose ideas were enacted more frequently on the focal and non-focal teams. These surprising findings might have been explained by analyzing gender from other conceptualizations. For example, women appeared to adopt strategies, which I outlined in Chapter 6 and Chapter 7 (e.g., meticulous preparation, clearing the floor for other women), to ensure their ideas were heard and enacted, which might explain the findings in the quantitative strand.

Conversely, while students did not describe race as a contributing factor in their experiences in the quantitative strand, racial/ethnic categories were significant factors in the quantitative strand. Notably, underrepresented minority students and Asian students appeared less likely to have their ideas enacted, despite seemingly no differences in the degree to which they were perceived to have contributed ideas. In the final chapter, I conclude by discussing implications of the findings I discussed for theory, teaching and learning, and future research on team-based pedagogies in engineering education.

Chapter 8: Discussion, Implications, and Conclusion

This study explored the role of the dominant epistemic values in engineering in shaping team-based engineering design processes. In particular, I examined the ways that Eurocentric epistemologies, most prominently adherence to scientific objectivity, appeared in first-year students' design teams in ways that shaped the ideas teams pursued and discarded, processes of communication and interactions, and patterns of influence over the course of a team-based, cornerstone engineering design project.

Guided by Critical Race Theory, critical feminist and sociology of technology literature that suggests dominant epistemologies in engineering marginalize the work and contributions of people of color and women in the discipline, I sought to understand how Eurocentric epistemologies might be implicated in processes of inequity in student design teams. This research was guided by four questions:

1. How do Eurocentric epistemologies shape the ideas that first-year engineering students consider, pursue, and discard individually and in design teams in a first-year design course?
2. How do Eurocentric epistemologies influence student interactions and status hierarchies of student design teams?
3. How do Eurocentric epistemologies shape the action opportunities, performance outputs, performance evaluations, and influence on student design teams?

4. How do Eurocentric epistemologies manifest in first-year engineering design teams in ways that might marginalize the work and contributions of students of color and women?

To answer these questions, I used a convergent parallel mixed-methods design (see Figure 4), combining a qualitative critical ethnographic strand with a quantitative social network analysis strand. Data collection in the ethnographic strand included semester-long observations of three focal engineering design teams in a first-year cornerstone design course, as well one-on-one interviews with each of the 15 students in the focal teams following their design team experiences. I also collected journals from the peer mentors in the course to gather information about the non-focal teams in the study.

In the quantitative strand (see Figure 4), I used three surveys to collect information on students' epistemological beliefs, as well as their perceptions of idea contributions and enactments in their teams over the course of the project. In the Beginning of Term survey administered prior to the start of the project, students responded to Engineering-Related Beliefs survey (ERB), which measured their beliefs about process objectivity, product objectivity, and depoliticization in engineering. In the Group Communication Survey administered after students joined their respective teams and began negotiating ideas, students provided their perceptions about whether or not they believed their teammates were frequently contributing ideas. Finally, in the Midterm Survey, students responded providing their perceptions about whether or not their teammates ideas were actually enacted during the project.

Consistent with Creswell and Clark's (2017) description of convergent parallel designs, I analyzed the qualitative and quantitative data separately, followed by a merging process wherein data from the two strands were compared for further analysis (Creswell & Clark, 2017). This process, for example, led me to expand the quantitative analysis from analyzing students' contributions to their design teams alone, to analyzing data on both contributions and enactments (i.e., the ideas teams actually used in their designs) in the quantitative strand.

My analysis was guided by five propositions surrounding a set of sensitizing concepts from Status Characteristics Theory—diffuse and specific status characteristics, as well as the four behavioral sequences (i.e., action opportunities, performance outputs, performance evaluations, and influence). I used these propositions to focus my analytical attention on students' epistemological beliefs in the qualitative and quantitative strands of the study. While the propositions employ sensitizing concepts from SCT, this study did not entail a full application of the theory. Instead, the behavioral sequences posited by SCT guided my observations (e.g., see the Observation Protocol, Appendix B), interviews, and coding, as well as the quantitative data collection and analysis.

Proposition 1 related adherence to scientific objectivity to status in teams, stating that engineering students whose epistemological perspectives aligned with dominant epistemic values will become high-status members on their teams. Similarly, Proposition 2 related adherence to scientific objectivity to status and resulting behavioral sequences, stating that students who adhere to scientific objectivity will earn higher status, which in turn will result in more action opportunities and performance outputs. Proposition 3 posited that engineering students who adhere to the scientific objectivity will receive more positive performance evaluations in team settings. Proposition 4 related adherence to scientific objectivity to influence on teams, stating students who adhered to scientific objectivity might exert more influence, defined as the ability to modify opinions, decisions, or behaviors, in their teams (Simpson et al., 2012). Finally, Proposition 5 posited that status characteristics, such as race/ethnicity and gender, will inform the degree to which adherence to scientific objectivity results in higher status on design teams.

While each proposition references three characteristics of Eurocentric epistemologies—scientific objectivity, value-neutrality, and depoliticization—I found that students' adherence to scientific objectivity was the most prominent epistemological influence on the work in their design teams. To understand how Eurocentric epistemologies—most notably scientific objectivity—influenced both individual students and teamwork, I analyzed qualitative data from ongoing observations of three focal design teams and individual interviews with the 15 members of these three focal teams. During the interviews, students discussed the first of their course requirements, the development of their individual design proposals, in order to describe how Eurocentric epistemologies appeared in students' design processes at the individual level. Finally, to understand how patterns from my observations might have appeared in the nine non-focal teams from the introduction to engineering course I studied, I analyzed responses from the peer mentors assigned to the ENGR 100 design teams.

As I analyzed the fieldnotes from my observations, one-on-one interviews, and peer mentor journals, I coded for the sensitizing concepts I described in Chapter 2. For example, I coded for the types of knowledge students relied on during the individual design process, as well as during team interactions, in order to understand the role of Eurocentric epistemologies during the design process. I also coded for the four behavioral sequences posited by SCT (i.e., action opportunities, performance outputs, performance evaluations, and influence) in order to understand the role of Eurocentric epistemologies in shaping individual and team behaviors.

In the quantitative strand, I began by developing and measuring the degree to which students elevated Eurocentric epistemic values using the Engineering-Related Beliefs (ERB) scales described in Chapter 2. Second, I used network analysis, estimating a multilayer exponential random graph model (i.e., multilayer ERGM). On the first layer of the multilayer ERGM, ties represented perceptions that students were frequent idea contributors during the early stages of the project. Ties on the second layer represented perceptions that a student's ideas were enacted (i.e., utilized) during the team's design process. I tested for popularity, sociality, and homophily effects by the three key status characteristics—race/ethnicity, gender, and process objectivity beliefs as measured by the ERB scales.

Findings

In the paragraphs that follow I summarize the main findings from the study. The findings are organized as they relate to the four guiding research questions. To answer the first two research questions, I drew on the qualitative findings. The answers to the third and fourth research questions rely on data from both the qualitative and quantitative strands of the study.

My first research question asked the how Eurocentric epistemologies shape the ideas that first-year engineering students consider, pursue, and discard individually and in design teams. The pattern I described as Manifestation 1, which identified the role of scientific objectivity to both the individual and team design processes, provided the clearest evidence related of how Eurocentric epistemologies shaped the ideas students pursued individually, as well as focal team interactions around their design projects. Specifically, I found that some students discussed struggling to develop their individual design proposals and hesitated to pursue particular ideas in their individual design proposals due to concerns that they could not defend their ideas with appropriate knowledge (i.e., research, technical support). Other students, in contrast, expressed relying on their prior experiences without explicit references to the math, science, and research underlying their ideas. This is important because it suggests that the normative supremacy of

Eurocentric epistemologies shaped students' approaches to design even before they enter their teams.

Eurocentric epistemologies similarly shaped the design process once students were in their teams. At the team level, I found that students' concerns related to adhering to Eurocentric epistemologies at the individual level appeared to shape the ideas teams pursued. While some students reported withholding, withdrawing, or not advocating for particular ideas in light of their concerns that they did not have appropriate support for their ideas in their teams. This suggests that the same concerns about adhering to the normative supremacy of Eurocentric epistemologies that led students to avoid particular ideas at the individual level also shaped the ideas teams pursued.

The second research question asked how Eurocentric epistemologies influence student interactions and status hierarchies of student design teams. Related to this research question, evidence from Manifestation 2, which described the role of technical tools, such as CAD models, to the ways that students communicated and enacted ideas during the design process, Manifestation 3, which revealed how scientific objectivity shaped team interactions, and Manifestation 4, which identified the use of what I called "meticulous preparation" by some students who sought to elevate their design ideas.

Manifestation 2 identified the role of technical tools, notably CAD models, as mechanisms that positioned some students as gatekeepers to ideas. Since students were required to implement ideas in SolidWorks (i.e., CAD software), the students assigned the CAD wielded influence over the team's design process, even if that influence was at times unconscious or unintentional. However, the need to implement ideas in SolidWorks was nonetheless a barrier to ideas when students' struggles with the software precluded one team from pursuing its initial design concept and required others to modify ideas in light of the need to support their ideas using the CAD model.

Also related to the second research question, Manifestation 3 documented rhetorical shifts in which students appeared to present the same ideas using different sources of knowledge as support. These rhetorical shifts included "scientizing" ideas—presenting ideas using technical knowledge in order to avoid or stop their ideas being from being discarded. That some students attempted to leverage technical knowledge to elevate or undermine particular ideas suggests an awareness that Eurocentric epistemologies often serve a legitimizing role in perceptions of ideas and contributions, which points to the normative supremacy of Eurocentric epistemologies in these first-year courses.

While "scientizing" ideas alone points to the normative supremacy of Eurocentric epistemologies, namely scientific objectivity, the social context in which these instances offer a richer answer to the second research question. For example, in previous chapters, I noted that rhetorical shifts were particularly prevalent at times when students' ideas were under threat of being undermined or discarded. I argue that rhetorical shifts, in combination with the context in which they occurred, suggest the normative supremacy of Eurocentric epistemologies shape status and influence on students' design teams. I argue that the fact that these instances occurred during moments in which ideas were threatened suggests students had an implicit understanding that adhering to scientific objectivity might help elevate ideas and enhance influence in engineering design teams.

Further related to the second research question, I discussed how Eurocentric epistemologies shaped team-based design processes in ways that were less overt. For example, Manifestation 4 shows how some students' need to adhere to normative Eurocentric epistemologies led them to prepare their ideas more thoroughly outside of the team setting seemingly in order to avert opposition to their ideas when those ideas were presented to the team (i.e., Manifestation 4). Again, the meticulous prior preparation of ideas points to the role of Eurocentric epistemologies in shaping status and influence; that some students believed developing strong support might help establish the legitimacy of their ideas suggests an implicit awareness of the role of Eurocentric epistemologies in legitimizing or delegitimizing particular ideas.

However, this need to prepare meticulously prior to presenting ideas was not shared by all students—while some students described preparing ideas outside of the team setting, other students appeared willing to "throw ideas at the wall" during team meetings. While some students tried to clarify ideas in advance of a team meeting by documenting their ideas and gathering support in order to ensure their ideas would be heard, as well as to increase the chances that their ideas would be enacted, it appeared that other students operated without prior meticulous preparation by "throwing ideas at the wall" or clarifying ideas during team meetings. I argued that the perceived need to adhere to scientific objectivity is not shared by all students in engineering design teams, and that this inequity is one way that Eurocentric epistemologies shapes interactions and hierarchies in design teams.

The third research question asked how Eurocentric epistemologies influence status hierarchies in teams, including the action opportunities, performance outputs, performance evaluations, and influence on the teams. In the quantitative strand, I examined action opportunities as the frequency of students' idea contributions to their teams, as well the nature by which certain ideas were enacted in each team while others were discarded. The finding from the descriptive analysis that enactments were more centralized than contributions, in concert with the ways I observed students elevate particular contributions, suggests Eurocentric epistemologies might be one mechanism by which idea contributions become enacted in teams. For example, the third manifestation of Eurocentric epistemologies—*rhetorical shifts*— described moments during which students appeared to turn to technical engineering knowledge in order to elevate or undermine particular ideas. These moments suggest that elevating scientific objectivity, resulted in higher status and greater influence on teams. Moreover, at times adherence to scientific objectivity led to increased action opportunities, such as opportunities to present and clarify ideas in the team setting. If students can turn to technical knowledge in order to salvage ideas under threat, then it appears that communicating ideas using technical knowledge operates to grant students status, influence, and action opportunities on teams on their teams.

Conversely however, Manifestation 6 revealed how technical knowledge was seemingly rejected in favor of the knowledge of "trusted" students, which suggests that adherence to scientific objectivity did not always result in higher status and greater influence. These findings point to equity issues on the design teams. Evidence from the quantitative strand supported the idea that the frequency of contributions was reinforced by the frequency of enactments, which represent the degree to which their teams actually used a particular students' ideas. While this is not surprising, if it is the case that some students' contributions were systematically undermined and participation was not equitable due to the ways that Eurocentric epistemologies are weaponized, while some "trusted" students were not scrutinized in the same way, the opportunities to turn idea contributions into enactments might become even more fraught by the power dynamics of the team.

Additionally, findings in this study reveals that students' enactments of epistemological values were shaped by social context of the team. In Chapter 2, I discussed the *domain specificity* of epistemological beliefs, suggesting students' engineering-related epistemological beliefs might not align with their epistemological beliefs in other disciplinary contexts. However, this study demonstrates that even within the same disciplinary context, students' enactments of epistemic values were not necessarily consistent with their responses to abstract survey questions about epistemological beliefs. Instead, as a student on one of the focal teams suggested, students relied on particular epistemic beliefs and values (i.e., scientific objectivity) selectively and in concert with their reading of the social context of the team in particular moments.

Finally, the fourth research question in this study asked how the dominant epistemic culture of engineering works to marginalize students of color and women in engineering design settings. In the quantitative strand, I estimated a multilayer ERGM to examine the role of race/ethnicity, gender, and epistemological beliefs (i.e., process objectivity beliefs) in (a) the contributions layer, (b) the enactments layer, and (c) the relationships between contributions and enactments. I did not find racial/ethnic or gender differences on the contributions layer. However, process objectivity similarity effects were significant on the idea contributions layer. As for the enactments layer, I found no gender differences on the idea enactments layer; however, two racial/ethnic categories—underrepresented minority status and AAPI status—were statistically significant and negative on the enactments layer, suggesting these students were less likely to be reported by their teammates as having their ideas enacted on their teams. Finally, one cross-layer dependence term, the reinforcement configuration, was significant and positive in the model, suggesting students who frequently contributed ideas were more likely to have those ideas enacted in their design teams.

To explain some of the surprising findings about race/ethnicity and gender in the quantitative strand, I drew on the peer mentor journals, as well as reflections from students from the focal teams in one-on-one interviews, to describe the ways that students discussed the role of race/ethnicity and gender in their engineering experiences broadly and their design experiences specifically. While I found that underrepresented minority and AAPI students' ideas were enacted on their teams less often than their counterparts, I also found that students of color in the focal team rejected the idea that race or racism had shaped their experiences in their respective teams. Although underrepresented minority students and AAPI students appeared to have their ideas less frequently enacted in the quantitative strand, the fact that none of those students pointed to race and racism when I asked about this possibility might underscore the subtle, yet harmful, nature of Eurocentric epistemologies in shaping racialized experiences in engineering.

Conversely, both women and men in the focal teams, as well as peer mentors reflecting on the non-focal teams, discussed how gender—most prominently the treatment of women in the focal and non-focal teams—shaped the design process in their teams. In the quantitative strand, I was surprised by the finding that there were no statistically significant differences in the contributions and enactments by gender because in the qualitative strand, I documented how men and women in the focal teams, as well as peer mentors pointed to gendered experiences (e.g., patterns of interruptions, undermining women's ideas, changing women's work without their input) that shaped the design process. Interestingly, in my fieldnotes, during interviews, and in my analysis of peer mentor journals, I noted seemingly strategic behaviors (e.g., clearing the floor for other women, meticulous preparation) that some women employed to navigate their gendered experiences. The surprising findings in the quantitative strand are thus a reflection of sexism in engineering, rather than evidence of its absence. Women in the focal teams explicitly or implicitly acknowledged gendered marginalization in their teams and worked to strategically circumvent that marginalization (e.g., clearing the floor for other women). These strategies to be heard might be one reason that anticipated gaps in contributions and enactments did not appear in the quantitative strand.

Discussion

Findings from this research add to existing literature on (a) processes of marginalization in STEM education, (b) engineering design studies, and (c) personal epistemologies in education broadly, and engineering education specifically. In the next sections, I situate these findings in existing literature by discussing how these findings align with, support, and expand existing research. I also consider how my findings might inform future research by discussing implications of this research for theory and methodology.

Marginalization in Engineering: Connections to Eurocentric Epistemologies

Existing literature describes how marginalized students must develop strategies for navigating conflicting epistemologies and epistemic dominance in the discipline (Carter et al, 2019; Cech et al., 2017). One such strategy, it appears, is to rely on Eurocentric epistemologies, particularly in moments during which ideas were threatened (see Danish, Team Surge), or to circumvent potential criticisms altogether (see: Lauren, Team Surge). However, this strategy was not always successful (see: Addy, Team Mobula), and resulted in varying patterns of influence on the focal teams. Data from the peer mentor journals helped shed light on how these dynamics played out in the non-focal teams. For example, one peer mentor noted that while the women on their team appeared to provide the most support for their ideas, their ideas contributed less to the design, suggesting adhering to Eurocentric epistemologies did not afford all students the same benefits during the design process.

That some students appeared to adopt strategies in order to ensure their ideas were heard, and to perhaps have their ideas elevated and selected by their team, is consistent with other research on racialized and gendered marginalization in STEM contexts. For example, McGee & Martin (2011) described stereotype management, which they defined as the "tactical responses to the ongoing presence of stereotype threat" (p. 1354). Similar to the finding in this research, where I describe students' meticulous preparation as a mechanism by which students attempted to circumvent the ways that Eurocentric epistemologies might undermine their ideas and contributions, McGee and Martin described Black students' strategies, such as the drive to "always being on point" particularly in mathematics, science, and engineering-related work (i.e., preparing and exceling precisely to undermine narratives that Black students are ill-equipped to perform in STEM). Just as I described Lauren's, a White woman's, need to prepare meticulously outside of the classroom as a burden that did not appear to be shared by her teammates, as well as Addy's, a Black woman's, excessive use of technical knowledge during her design discussions, McGee and Martin described the need to "always be on point" as an undue "burden" that students used "to rescue themselves from being judged as less worthy or less capable of academic excellence" (p. 1367).

Still, a core tenet of CRT, whiteness as property, frames whiteness as alienable, but characterized in part by exclusivity (Harris, 1993). In this study, whiteness as property manifested in an adherence to Eurocentric epistemologies. In alignment with this tenet of CRT, while the benefits of whiteness were conferred, albeit at times partially, on non-Whites who adhere to its tenets (e.g., Danish's use of rhetorical shifts), those benefits could be and were revoked, particularly by Whites who possessed and deployed the material benefits of whiteness. Perhaps the same can be said of the material benefits of "man-ness" in engineering—implicit trust, high performance expectations, and the like are conferred on women who adhere to Eurocentric epistemologies by supporting their ideas steadfastly with technical engineering knowledge. This helps explain Lauren's meticulous preparation of her ideas before team meetings—she hoped that her team would listen to her if she came well-prepared to defend her ideas. While Lauren's efforts were successful—the team chose to pursue her ideas—this benefit, was seemingly denied to Addy. Though she came prepared with calculations and support, the benefits one might anticipate from such preparation—the trust afforded to Kevin—were not afforded to her.

Implications for Teaching and Learning in Engineering

Christensen and Ernø-Kjølhede (2008) began by posing the question, "Is it relevant and meaningful for engineering students and teachers to engage in philosophical questioning and is philosophy of science a natural part of the curriculum for students of engineering?" (p. 561). While they worked to examine engineering instructors' knowledge and attitudes towards these issues, I hope to advance an argument for the inclusion of discussions of engineering epistemologies in engineering education broadly, and in team-based pedagogies specifically.

A growing body of research in engineering education is establishing the importance of connecting engineering work to relevant social, political, economic issues and the like (Ro et al., 2015). However, I argue it is not just the relationship between technical engineering knowledge and social and political issues that is important. The ways we as engineers think about engineering knowledge itself shapes the artifacts we build and, as a result, its relationship to the relevant issues described above. This dissertation research demonstrates that students are aware, at least implicitly and at times explicitly, of dominant ways of thinking and knowing in engineering. The inconsistency in their use of these dominant ways of thinking provides opportunities for learning about engineering work as well as about how racism and sexism can impede that work, harming not only individual engineers but the communities that are affected by the products, processes, and systems engineers design.

Specifically, this research demonstrates that students' awareness of dominant epistemologies in engineering shaped their approaches to the design process at both the individual and team levels in ways that precluded or elevated ideas during the design process. Thus, the answer to Christensen and Ernø-Kjølhede's (2008) question is a resounding yes. This research demonstrates that unexamined philosophical assumptions about knowledge shape students' approaches to team-based design, whether instructors broach these topics or not. Addressing the role of such assumptions in team communication and decision making is a pedagogical imperative. For example, engineering design instructors should introduce the concept of epistemologies in their courses so that students become aware of how their beliefs and assumptions influence their thinking about engineering problems. Prompting students to document and question their assumptions about what is, and is not, legitimate and valuable knowledge in engineering might be one step in making the role of Eurocentric epistemologies in individual and team-based design processes clearer to engineering students.

It would also be useful for instructors to explicitly note the values that engineers have traditionally excluded from consideration in engineering practice, and the harm that exclusion does to engineering students, engineering teams, and engineering work. For example, Cech and colleagues (2017) documented the role depoliticization plays in harming engineering students from Indigenous background, such as the ways that credentialling processes and pedagogical practices in science, engineering, and health fields often force Indigenous students to engage in practices (e.g., dissection in laboratory courses) that conflict with, rather than draw on and reinforce, their beliefs. In order to design more inclusive educational experiences, instructors need to develop understandings of how accepted Eurocentric epistemologies may exclude students. Instructors should also guide students in understanding those processes of exclusion and their effects in order to build more inclusive classrooms.

In a study of the classroom situations that provoke pre-college STEM students to use evidence-based reasoning, Siverling and colleagues (2021) argued that both instructor's pedagogical practices, as well as student-directed communication, can influence students' use of argumentation and evidence-based reasoning.[10] Their study found evidence-based reasoning in teacher-prompted episodes when (a) students justified ideas to respond to adults in the room and (b) students needed to document information for their projects. While they argued that simple yes/no questions were at times sufficient to elicit reasoning, they also noted that other questions (e.g., containing the word *why* and asking for data) were more successful in getting students to describe design ideas and provide rationale.

The pedagogical goal I am promoting is not necessarily evidence-based reasoning. Rather, I am hoping to promote an engineering culture where various sources of knowledge are considered useful. Indeed, I argue even evidence-*less* ideas can be powerful learning opportunities for students to pursue in team-based design settings. As I argued in previous chapters, if students do not pursue ideas due their inability to provide evidence-based reasoning, as I found in this study, learning opportunities that entail clarifying ideas in team settings are missed, and innovative ideas and concerns about the impacts of design choices might not be considered, impacting the learning of the entire team.

I do not mean to suggest that the use of evidence-based reasoning is an inherent signal of bias and marginalization or that math and science are inherently mechanisms of racism and

---

[10] Siverling and colleagues (2021) acknowledge that the terms "argumentation" and "evidence-based reasoning" are used, at times, interchangeably. However, the terms are not necessarily synonymous.

sexism in engineering. As Dym et al. (2005) note, math and science are often viewed as the language of the discipline of engineering, and eventually, it is an essential requirement that students learn to communicate ideas in terms consistent with the language of the discipline. However, the setting for this research study was an engineering learning environment, where it appears the need to adhere to the language of the discipline might be undermining key learning goals, such as the equal participation and contributions, associated with positive learning outcomes in project- and team-based learning experiences.

Moreover, this research suggests the requirement of speaking in the ubiquitous language of the discipline is not borne by all students during the design process, and the inequity in how students perceive and respond to these requirements affects (a) the ideas they bring to their design teams, (b) the ideas they are or are not willing to advocate for in team settings, and (c) the ultimate product of the team's work—the design itself. That some students felt freer to rely on their personal experiences, guesswork, or intuition while others felt beholden to the normative supremacy of Eurocentric epistemologies appeared to result in varying patters of contributions, enactments, and influence on the teams.

That there appears to be different standards by which some students do or do not feel required to adhere to Eurocentric epistemologies has equity implications beyond the communication patterns I documented in this study. For example, Norström (2013) noted the utility of "non-scientific models," such as experiential knowledge, folk theories, and obsolete scientific knowledge in educational settings, arguing that students should be allowed to use non-scientific models when engaging in design work. The results of this study suggest this is particularly important in team-based engineering design education settings, where the need to adhere to scientific models might form the basis of process of exclusion in students' teamwork.

Instructors should make explicit the potentially powerful role that non-scientific models—prior experiences, folk theories, non-book learning, personal values, and alternative epistemologies—can play in improving the engineering design process both at the individual and team levels.

How might an engineering design instructor design activities that position students to reflect on, question, and utilize their prior knowledge, beliefs, and values? In an articulation of a Tribal Critical Race Theory, Brayboy (2005) noted that "Indigenous peoples have a desire to obtain and forge tribal sovereignty, tribal autonomy, self-determination, and self-identification" (p. 429). An engineering instructor could prompt students to consider how such desires might inform the ways that students engage in teams, as well as how such design might shape students' thinking about the design process. For example, how might the desire for sovereignty, autonomy, self-determination, and self-identification inform Indigenous students' priorities in a community-based design project? How might these desires inform the ways these students interact in teams or with communities for which they are design new technology? How might normative, widely legitimized beliefs about objectivity and neutrality force students who value sovereignty, autonomy, self-determination, and self-identification to reject those values during the design process? Prompting students to reflect on, explicate, and utilize their beliefs and values, as well as the beliefs and values of the communities they serve, can legitimize those beliefs and values and invite students and stakeholders to participate fully in a collaborative design process.

Norström (2013) similarly argued for the inclusion of non-scientific models in engineering and technology design education. Yet, Norström observed a contradiction, arguing that design education should both complement science education as well as reflect real-world engineering design work. The former requires centering scientific models in engineering work, while in practice, engineers often draw on non-scientific models, thus making the centering or requiring of scientific models in engineering design education potentially counterproductive. Addressing this contradiction is an important aspect of supporting students' full participation because it both acknowledged the role of traditional engineering knowledge (e.g., math and science), but also its limits, in engineering design education.

Kolmos & de Graaff (2014) contend that team-based learning experiences, such as team-based engineering design courses, position learning as a social process "in which learning takes places through dialogue and communication" (p. 149). The goal of a team design project is not simply to solve the problem, but to construct knowledge in collaboration with other students. This dissertation research joins a long line of studies of design experiences that demonstrate how processes of inequity preclude some students from participating fully and equitably in the learning experience, thereby shaping the learning of all students involved (e.g., Beddoes & Panther, 2017; Wolfe & Powell, 2009). If students are withdrawing, withholding, or not advocating for ideas, important learning opportunities, such as team negotiations, might be missed. This study reveals the irony that learning opportunities are missed precisely because some students believe that have not already done the learning that is being asked of them in the present.

How, then, should engineering design instructors support the inclusion of non-scientific models and prevent the normative supremacy of Eurocentric epistemologies from marginalizing the work and contributions of students of color and women? I argue for constructing educational activities that ask students to specifically relate their ideas and concepts to the potentially non-scientific (i.e., guesswork, intuition, experiential knowledge) they drew on. While Siverling and colleagues (2021) noted that questions including the word *why* and requesting data or evidence elicited evidence-based reasoning from students, I contend that questions like *where* did these ideas come from might elicit the non-scientific sources students drew on. Normalizing non-scientific sources of knowledge and support for its role in learning in the classroom can also be a powerful pedagogical practice for supporting students in team-based engineering design settings. This might be particularly important in first-year cornerstone courses where students should be encouraged to openly acknowledge the limits of their knowledge to make their thinking visible, as well as to discourage the weaponization of math, science, and technical knowledge to simply undermine potentially valuable ideas. Rather, all of these sources of knowledge can be tools to be used constructively to build on what students already know and their innovative ideas.

Implications for Research and Methods

Methodological Issues for Studying Epistemologies in Teamwork

Louca and colleagues (2004) discussed the distinction between professed epistemologies and enacted epistemologies. One's professed epistemologies, defined as "stated views about knowledge and learning," which I suggest appear in responses to survey questions like the ERB survey in this study, need not align with one's enacted epistemologies, "the views about knowledge and learning an observer would infer from classroom behaviors" (p. 59). Louca and colleagues argued that "neither the professed nor enacted epistemology is...the true epistemology" (p. 59), and instead, we might view the difference between professed and enacted beliefs as a matter of different resources being utilized in particular contexts.

The results of this study support this claim. For example, the rhetorical shifts I described in Chapter 6 suggest that students deployed particular types of knowledge depending on social context. Whereas some students operated free to rely on their prior experiences, others relied on technical engineering knowledge in moments of disputes when their ideas were being threatened. This suggests, as Louca and colleagues argue, that different contexts activate different resources.

However, that some students relied on various forms of knowledge differently than their peers suggests equity issues in how these various forms of knowledge operate in design teams.

More importantly, such discrepancies between professed and enacted epistemologies calls into question the use of quantitative instruments measuring epistemological beliefs. In Chapter 2, I noted that number of existing instruments measuring epistemological beliefs exhibit low internal consistency. In Chapter 3, I similarly documented the low internal consistency of the scales I developed for this study. It might be the case that students' responses reflect a wide variety of potential social contexts. What does one believe in the moment while responding? What does one believe in the abstract? What does one believe in a hypothetical engineering setting they have constructed in their own mind? What does one believe based on prior engineering experiences? All of these might engender vastly different responses from person to person, much less across individuals, in ways that inform the quantitative findings of this study.

Still, even if students' responses to ERB items were a perfect representation of what they believed in practice, *what* they believed proved to be equally important as *why* they appeared to believe it. For example, several students from the three focal teams who articulated support for process objectivity did so under the premise of exerting influence in engineering teams. Those students felt it necessary to articulate ideas in terms of existing research or mathematics and scientific concepts, even in moments when those concepts eluded them, in part because they believed it was the best approach to elevating ideas.

In this way, using the term epistemological *beliefs* is, perhaps, a misnomer. Louca and colleagues (2004) argue the term *belief* implies stability, and that the assumption that epistemological beliefs are relatively stable support particular methodological approaches to studying epistemologies, such as interviews and surveys. However, evidence from my observations suggested the types of knowledge students drew on, which is arguably a more authentic way to examine their epistemologies, was not always consistent, even from moment to moment during particular meetings. Instead, students' epistemologies appeared not only domain-specific, but also context-dependent and socially situated.

Nonetheless, students' survey responses captured *something* about their perspectives on engineering knowledge and its relationship to engineering practice, even if that *something* was abstract and changing, different, adjustable, or altogether abandoned in practice. What, then, can we say about students' epistemologies based on both individual and collective responses to the epistemological beliefs survey administered at the beginning of the term? First, an inspection of students' scores (Appendix H) across the scale factors indicates that clearly some students elevate the normative supremacy of Eurocentric epistemologies (i.e., large positive scores) far more than their peers (i.e., large negative scores). If it is true that these beliefs about knowledge in engineering shape complex problem solving, including the ways students interpret problems, their problem-solving strategies, and, as this study also demonstrates, the types of knowledge they draw on during the problem-solving process, clearly these differences can affect team-based strategies. I discuss these in the next sections.

Other methodological issues for studying epistemologies include approaches to studying epistemologies in team-based social settings. One common approach to analyzing interactions in team-based learning settings, including engineering design settings, is to observe and record students' interactions, documenting and coding conversations (i.e., utterances). For example, Stempfle & Badke-Schaub, 2002) recorded design teams engaged in a one-day, complex design problem in a laboratory setting. Stempfle and Badke-Schaub then coded "communicative acts" over the course of the design process, focusing particularly on content of the design problem and the organization of the teams' working processes. However, the richness of participant observation as a data source lies in the researcher's ability to document not just events, but how events unfolded, as well as the effects those events have on the social environment the ethnographer is observing. From this, speculations and deductions about intentions (i.e., what lies behind comments and behaviors) and results (i.e., of particular behaviors) arise in the analytical process. This is process is enhanced when observations are repeated, intensive, and long-term, which Maxwell (2013) suggests can allow a researcher check and confirm inferences.

Over the course of the project, it became clear that documenting and coding students' words in the moments did not adequately capture the nature of their ideas, their approaches to elevating ideas, or the ways that social context shaped interactions. For example, in Chapter 6, I discussed the nature and use of questions and, at times, described speculations and deductions I made about students' intentions. As a matter of methodology, I returned to my speculations and deductions about intentions and results during individual interviews to ascertain the degree to which my speculations and deductions aligned with participants and other individuals (e.g., peer mentors, instructors) in the study.

Situating students' conversations in a broader context of their team (e.g., between meetings, in light of external influences such as their personal learning goals) helped me understand that some interactions and conversations were not as straightforward as they appeared on their own. Danish's (Team Surge) pressing the team to "name the negatives" of his Trapezoid Frame idea might at first appear to be an earnest attempt to discuss his ideas. However, in the context of the contentious meeting during which the team argued over several ideas, his prior comments that the team would pursue his idea during the Preliminary Design Review, and his prior opposition to other frame concepts, his question to his teammates to "name the negatives" does not appear to be an earnest question at all. Instead, I interpreted to be a mechanism by which Danish attempted to elevate his Trapezoid Frame idea.

Stempfle and Badke-Schaub (2013) note that in laboratory studies it is "easily possible to induce the same task with the same embedded context for different groups" (p. 479). While they also admit that researchers must be cautious making generalizations from studies in laboratory settings, they also argue that "unknown and unpredictable factors" contaminate studies conducted outside of laboratory settings (p. 479). This may be a necessary methodological tradeoff in studying the role of epistemologies in engineering design. My conclusions about interactions in the focal teams were the product of both behavioral indicators (i.e., words used in conversation) themselves, as well as my understanding of the broader context in which those interactions occurred. I viewed these "contaminating elements" as important contextual factors necessary for explaining the qualitative and quantitative results of this study. My findings indicate epistemological perspectives are socially situated, manifesting in different ways depending on the *who* and *why* of the design team.

Future research might explore when and how these beliefs change over time as the result of students' experiences in engineering design settings. Future research might also further examine the conditions that influence the ways that students do or do not adhere to Eurocentric epistemologies. Wise and colleagues (2004), for example attributed rapid changes in fourth-year engineering students' epistemological beliefs to team- and project-based learning experiences. In this study, some students appeared more willing to elevate Eurocentric epistemologies after describing their positive engineering experiences. Moreover, since one of the findings in this study suggests some students were prone to relying on Eurocentric epistemologies, future research might explore how these ideas spread among team members over time, including who feels increased burden to adhere to Eurocentric epistemologies, as well as who might appear to be immune to the burden of Eurocentric epistemologies in team-based design settings.

Methodological Issues for Studying Race and Gender in Engineering

This study is not the first to suggest women and students of color in engineering experience systematic processes of marginalization in the discipline broadly, and in team-based design learning more specifically (Fowler & Su, 2018; Strehl & Fowler, 2019; Wolfe & Powell, 2009). The body of literature documenting experiences of racialized and gendered hostility in engineering is substantial. Existing research also suggests team-based learning settings can become settings where both overt and covert racial and gender biases are manifested in ways that indelibly shape the learning environments that mean the benefits of project-based learning are not shared by all students (Wolfe & Powell, 2009).

In many studies examining race and gender, and by extension purporting to study racism and sexism, the "box-check" method, wherein race and gender is expressed based on the boxes students check (e.g., man, women, Black, Asian) on surveys, serve as key explanatory variables in models examining race and gender. This approach necessarily entails a number of problematic research practices: (a) collapsing racial categories in ways that obscure or erase lived experiences, (b) altogether erasing students who fit into racial/gender "other" categories (i.e., trans* or nonbinary students, multiracial/multiethnic students). However, as O'Connor and colleagues (2007) suggest, often these "boxes" serve as proxies for a nebulous "something else." This became immediately clear as I synthesized the quantitative and qualitative data in this research. For example, I was at first tempted to dismiss the non-significant gender findings in the study since the ENGR 100 instructors had purposefully avoided "stranding women" on teams by placing women on teams where they were always teammates with at least one other woman.

After I documented moments in the focal teams (i.e., Team Surge) during which Lauren and Stephanie appeared to work in tandem to provide each other opportunities to contribute to the team, I was tempted to suggest that this practice might underlie the non-significant findings in the quantitative strand.

However, upon engaging in intertextual reflexivity, as well as reviewing peer mentor data, I asked, “What was it I was hoping to capture about *gender* by including the binary “box” that students checked at the beginning of the term?” Implicitly, the boxes served as proxies for gendered communication dynamics that have been studied and documented across science, technology, engineering, and mathematics education literature on teamwork and project-based learning. For example, existing research indicates women in engineering are less likely to take on technical tasks in their teams (Fowler & Su, 2018; Meadows & Sekaquaptewa, 2013; Strehl & Fowler, 2019), are more likely to engage in “female typical speech acts” such as avoiding confrontational criticism and self-directed criticism (Wolfe & Powell, 2009), and that men tend to dominate speaking time in engineering teams (Lewis Jr. et al., 2019). All of these are expected to result in patterns of marginalization in teams that would be associated with the box, “gender,” in the quantitative analysis.

Evidence in the quantitative strand clearly indicated that these gendered processes were not common across the teams. Some women, according to their peer mentor’s subjective assessments, became leaders of their teams and led design discussions over the course of the project. As a result, in Chapter 7, I returned to a conceptualization of gender as *adherence to masculine norms*, in part, because the peer mentors pointed to the ways that women who were influential actors behaved on their teams, and those behaviors appeared to align with descriptions of masculine norms in the literature. In this way, the boxes in this study did not “work” to the extent that they did not adequately capture the “something else” about gender that appeared to shape patterns of influence on the teams.

Similarly, O’Connor et al. (2007) suggested race has been “undertheorized,” and that racial “boxes” might serve as proxies for things such as biology or culture. In this study, I attempted to theorize race as the degree to which students adhered to Eurocentric epistemologies in engineering. However, evidence from this study also suggests that the racial box was inadequate for capturing racial difference—students expressed tentative views about how they raced in engineering. Moreover, this study calls into question the degree to which adherence to Eurocentric epistemologies can be viewed as a proxy for race or racism in engineering.

Bonilla-Silva (2015) articulated the “superficial extension of the principles of liberalism to racial matters that results in ‘raceless’ explanations for all sorts of race-related matters” (p. 1364). Abstract liberalism, which elevates neutrality and objectivity (Lopez, 2003), can be wielded in ways that make people appear reasonable when behaving in unjust ways. To justify discarding Addy’s concept vessel or altering her work despite her calculations, students drew on math and science concepts, suggested her understanding was incorrect, and altered work, despite failing to produce calculations themselves. Ironically, it was Addy, a Black woman engineering student, who had the highest ERB score on her team, and supported her ideas with the calculations required of the course. Still, her work was altered in favor of a trusted male teammate using the familiar, yet superficial, language of mathematics and scientific objectivity.

This suggests the degree to which the racial boxes, as well as the ERB survey, served as a proxy for racial *something* is perhaps marginal. That superficial adherence could be wielded to undermine a student’s work suggests that Eurocentric epistemologies can act as mechanisms of marginalization. Moreover, that adhering to Eurocentric epistemologies by a student of color still failed to win over their team suggests the benefits of adhering to dominant epistemologies in engineering are not shared by all students.

Study Contribution

This study contributes to the research on team-based pedagogies by examining how dominant ways of knowing in engineering shape design processes in team-based learning settings. Drawing on the shared commitment of Critical Race and Feminist scholars for uncovering and addressing processes of inequity (i.e., racism and sexism), this study advances critiques of engineering education by demonstrating how the dominant epistemic culture of the discipline appears, at times covertly, in team-based engineering design processes.

Additionally, this study makes a methodological contribution. In the quantitative strand, I employed the multilayer extension of the exponential random graph model (ERGM) to educational data. I suggest the multilayer ERGM holds enormous potential for educational research broadly. Traditional methods to analyzing multiple relationships in networks in education studies entail analyzing the two relationships separately and then comparing or aggregating the two models to draw conclusions. However, in educational research where, for example, students, educators, and administrators might hold multiple relationships (e.g., classmate/non-classmate and teammate/non-teammate), or where students are embedded in classes, which are embedded in schools, and so on. To date, this study is the first time this approach has been used in educational research. I suggest this approach might hold enormous potential for future research in educational settings.

The results of this study are also a novel contribution of this research. While existing scholarship has posited ways that Eurocentric epistemic values appear in science, technology, and engineering settings, this research documented explicit, behavioral manifestations of

Eurocentric epistemic values. Understanding how Eurocentric epistemologies are manifested in social behaviors in teams moves the study of Whiteness and maleness, as embodied by Eurocentric epistemologies away from the abstract to the concrete. I argue these findings support additional research on racialized and gendered processes of marginalization in STEM education broadly, and engineering education specifically. This study underscores theoretical propositions about the role of racialized epistemologies by providing empirical evidence of the role these epistemologies have in shaping the ideas and contributions engineers elevate in their work.

Finally, this works points to directions for future research. Race and racism, as well as gender and sexism, have been undertheorized in existing literature in empirical studies of engineering education. This research points to racialized and gendered mechanisms of exclusions that shape students' learning in engineering. Addressing these issues, then, becomes an imperative of the discipline and the educators tasked with teaching the engineers of the future.

Conclusion

In this research, I described the ways that dominant, Eurocentric epistemologies in engineering appear in team-based engineering design processes at both the individual and team levels. While existing research posits Eurocentric epistemologies play a legitimizing role in STEM disciplines, often serving as an underlying mechanism elevating and marginalizing ideas and contributions in engineering, this study demonstrated how dominant epistemologies might work to preclude some students from full participation in team-based learning settings, thereby shaping all students' learning in their engineering design teams.

This research was borne of a commitment to eradicating the deleterious effects of racism and sexism often cited in engineering, both in educational and professional settings. While students in this study did not always point to gender and sexism, or race and racism, to describe their experiences in their design teams, this research indicates the normative supremacy of Eurocentric epistemologies has ongoing consequences to team-based learning in the discipline. As team-based pedagogies continue to grow in engineering education, addressing issues of equitable participation will continue to be a pressing need for engineering educators.

References

Alexander, B. K. (2003). (Re)Visioning the ethnographic site: Interpretive ethnography as a method of pedagogical reflexivity and scholarly production. *Qualitative Inquiry, 9*(3), 416 – 441.

Barger, M. M., Wormington, S. V., Huettel, L. G., & Linnenbrink-Garcia, L. (2016). Developmental changes in college students' personal epistemology profiles. *Learning and Individual Differences, 48*, 1 - 8.

Baxter-Magolda, M. B. (1992). *Knowing and reasoning in college: Gender-related patterns in students' intellectual development*. Jossey-Bass.

Beddoes, K. & Panther, G. (2018). Gender and teamwork: An analysis of professors' perspectives and practices. *European Journal of Engineering Education, 43*(3) 330 – 343.

Belenky, M. F., Clinchy, B. M., Goldberger, N. R., & Tarule, J. M. (1986). *Women's ways of knowing: The development of self, voice, and mind* (Vol. 15). New York: Basic books.

Bernal, D. D., & Villalpando, O. (2002). An apartheid of knowledge in academia: The struggle over the" legitimate" knowledge of faculty of color. *Equity & Excellence in Education*, *35*(2), 169-180.

Bianchi, A. J. (2010). Status characteristics/expectation states theory. In J. M. Levine & M. A. Hogg (Eds.), Sage Encyclopedia of Group Processes & Intergroup Relations (p. 845 – 848). Thousand Oaks, CA: Sage Publications, Inc.

Bonilla-Silva, E. (1999). The essential social fact of race. *American Sociological Review, 64*(6), 899 - 906.

Bonilla-Silva, E. (2015). The structure of racism in color-blind, "post-racial" America. *American Behavioral Scientist, 59*(11), 1358 – 1376.

Bowman, J. E. (2013). *Status processes and organizational inequality: The social psychology of inclusion* (Unpublished doctoral dissertation). Stanford University, Stanford, CA.

Brayboy, B. M. J. (2005). Toward a tribal critical race theory in education. *The Urban Review, 37*(5), 425 – 446.

Buehl, M. M. & Alexander, P. A. (2005). Motivation and performance difference in students' domain-specific epistemological belief profiles. *American Educational Research Journal, 42*(5), 697 - 726.

Burris, E. R. (2012). The risks and rewards of speaking up: Managerial responses to employee voice. *Academy of Management Journal*, *55*(4), 851-875.

Butler, J. (1988). Performative acts and gender constitution: An essay in phenomenology and feminist theory. *Theatre Journal, 40*(4), 519 – 531.

Cabrera, N. L. (2018). Where is the racial theory in critical race theory?: A constructive criticism of the crits. *The Review of Higher Education, 42*(1), 209 – 233.

Cabrera-Nguyen, P. (2010). Author guidelines for reporting scale development and validation results in the Journal of the Society for Social Work and Research. *Journal of the Society for Social Work and Research, 1*(2), 99 – 103.

Carberry, A. R., Lee, H., Ohland, M. W. (2010). Measuring engineering design self-efficacy. *Journal of Engineering Education, 99*(1), 71 – 79.

Carberry, A., Ohland, M. & Swan, C. (2010). A pilot validation study of the epistemological beliefs assessment for engineering (EBAE): First-year engineering student beliefs.

Cech, E. (2013). The (mis)framing of social justice: Why ideologies and meritocracy hinder engineers' ability to think about social justice. In J. Lucena (ed.), *Engineering Education for Social Justice: Critical Explorations and Opportunities* (pp. 67 - 84). Dordrecht: Springer.

Cech, E. A., Anneke, M., Smith, J. L., & deVries, K. (2017). Epistemological dominance and social inequality: Experiences of Native American science, engineering, and health students. *Science Technology, & Human Values, 42*(5), 743 - 774.

Cech, E. A., Metz, A., Smith, J. L., & deVries, K. (2017). Epistemological dominance and social inequlity: Experiences of Native American science, engineering, and healthy students. *Science, Technology, & Human Values, 42*(5), 743 – 774.

Cech, E. A. & Sherick, H. M. (2015). Chapter 9: Depoliticization and the structure of engineering education. In S. H. Christensen, C. Didier, A. Jamison, M. Meganck, C. Mitcham, & B. Newberry (Eds.) *International Perspectives on Engineering Education* (pp. 203 – 216). New York: Springer.

Chapman, T. K. (2013). You can't erase race! Using CRT to explain the presence of race and racism in majority white suburban schools. *Discourse: Studies in the Cultural Politics of Education*, *34*(4), 611-627.

Chen, T. H. Y. (2019). Statistical inference for multilayer networks in political science. *Political Science Research and Methods, 9*(2), 380 – 397.

Collins, P. H. (1991). *Black feminist thought.* New York: Routledge.

Corbie-Smith, G., Henderson, G., Blumenthal, C., Dorrance, J., & Estroff, S. (2008). Conceptualizing race in research. *Journal of the National Medical Association, 100*(10), 1235 - 1243.

Cranmer, S. J. & Desmarais, B. A. (2011). Inferential network analysis with exponential random graph models. *Political Analysis, 19*(1), 66 – 86.

Crenshaw, K., Gotanda, N., Peller, G., & Thomas, K. (1995). Introduction. In K. Crenshaw, N. Gotanda, G. Peller, & K. Thomas (Eds.), *Critical Race Theory: The Key Writings that Formed the Movement* (p. xii – xxxii). New York: New Press.

Creswell, J. W., & Clark, V. L. P. (2017). *Designing and conducting mixed methods research*. Sage publications.

Cristensen, S. H. & Ernø-Kjølhede, E. (2008). Epistemology, ontology and ethics: 'galaxies away from the engineering world'?. *European Journal of Engineering Education. 33*(5-6), 561 – 571.

DeBacker, T. K., Crowson, H. M., Beesley, A. D., Thoma, S. J., & Hestevold, N. L. (2008). The challenge of measuring epistemic beliefs: An analysis of three self-report instruments. *The Journal of Experimental Education*, *76*(3), 281-312.

DeCuir, J. T. & Dixson, A. D. (2004). "So when it comes out, they aren't that surprised that it is there": Using critical race theory as a tool of analysis of race and racism in education. *Educational Research, 33*(5), 26 – 31.

Denzin, N. K. (1997). Chapter 7: Ethnographic poetics and narrative of the self. In N. K. Denzin (Ed.), *Interpretive ethnography: Ethnographic practices in the 21st century* (pp. 199 – 228). Thousand Oaks, CA: Sage.

Desmarais, B. A. & Cranmer, S. J. (2012). Statistical mechanics of networks: Estimation and uncertainty. *Physica A: Statistical Mechanics and its Applications, 391*(4), 1865 – 1876.

Dinar, M., Shah, J. J., Cagan, J., Leifer, L., Linsey, J., Smith, S. M., & Hernandez, V. (2015). Empirical studies of design thinking: Past, present, and future. Journal of Mechanical Design, 137(2), 1 – 13.

Dringenberg, E. & Purzer, S. (2018). Experiences of first-year engineering students working on ill-structured problems in teams. *Journal of Engineering Education, 107*(3), 442 - 467.

Duncan, G. A. (2002). Beyond love: A critical race ethnography of the schooling of adolescent Black males. *Equity & Excellence in Education, 35*(2), 131 – 143.

Dym, C. L., Agogino, A. M., Eris, O., Frey, D. D., and Leifer, L. J. (2005). Engineering design thinking, teaching, and learning. *Journal of Engineering Education, 94*(1).

Dym, C. L. (1992). Representation and problem-solving: The foundations of engineering design. Environment and Planning B: Planning and Design, 19(1), 97 – 105.

Evans, N. J. (2011). Psychosocial and cognitive-structural perspectives on student development. In J. H. Schuh, S. R. Jones, S. R. Harper and Associates (Eds.), *Student Services: A Handbook for the Profession* (pp. 168 - 186). San Francisco: Jossey-Bass.

Faber, C. & Benson, L. C. (2017). Engineering students' epistemic cognition in the context of problem solving. *Journal of Engineering Education, 106*(4), 677 - 709.

Farber, D. & Sherry, S. (1993). Telling stories out of school: An essay on legal narratives. *Stanford Law Review, 45*(4), 807 – 855.

Fowler, R. R. & Su, M. P. (2018). Gendered risks of team-based learning: A model of inequitable task allocation in project-based learning. *IEEE Transactions on Education, 61*(4), 312 – 318.

Gainsburg, J. (2015). Engineering students' epistemological views on mathematical methods in engineering. Journal of Engineering Education, 104(2), 139 – 166.

Godfrey, E. (2014). Understanding disciplinary cultures. In A. Johri & B. M. Olds (Eds.), *Cambridge Handbook of Engineering Education Research* (pp. 201 - 225). New York, NY: Cambridge University Press.

Gonzalez-Sobrino, B. & Gross, D. R. (2019). Exploring the mechanisms of racialization beyond the black-white binary. *Ethnic and Racial Studies, 42*(4), 505 – 510.

Goodreau, S. M., Kitts, J. A., & Morris, M. (2009). Birds of a feather, or friend of a friend? Using exponential random graph models to investigate adolescent social networks. *Demography, 46*(1), 103 – 125.

Grincheva, N. (2013). Scientific epistemology versus indigenous epistemology: meanings of 'place' and 'knowledge' in the epistemic cultures. *Logos & Episteme*, *4*(2), 145-159.

Grunspan, D. Z., Wiggins, B. L., & Goodreau, S. M. (2014). Understanding classrooms through social network analysis: A primer for social network analysis in education research. *CBE—Life Sciences Education, 13*(2), 167 – 178.

Harding, S. (2001). After absolute neutrality: Expanding "science". In M. Marberry, B. Subramaniam, and L. H. Weasel (Eds.), *Feminist Science Studies: a new generation* (pp. 291 – 304). New York: Routledge.

Harper, S. R. (2010). An anti-deficit achievement framework for research on students of color in STEM. *New Directions for Institutional Research*, *2010*(148), 63-74.

Harrington, B. (2003). The social psychology of access in ethnographic research. *Journal of Contemporary Ethnography*, *32*(5), 592-625.

Heiskanen, H. & Lonka, K. (2012). Are epistemological beliefs and motivational strategies related to study engagement in higher education? *Procedia Social and Behavioral Sciences, 69,* 306 - 313.

Hofer, B. K. & Pintrich, P. R. (1997). The development of epistemological theories: Beliefs about knowledge and knowing and their relation to learning. *Review of Educational Research, 67*(1), 88 – 140.

Hofer, B. K. (2001). Personal epistemology research: Implications for learning and teaching. *Journal of Educational Psychology Review, 13*(4), 353 - 383.

Hofer, B. K. (2006). Domain specificity of personal epistemology: Resolved questions, persistent issues, new models. *International Journal of Educational Research, 45*(1), 85 - 95.

Hoff, P. D., Raftery, A. E., & Handcock, M. S. (2002). Latent space approaches to social network analysis. *Journal of the American Statistical Association, 97*(460), 1090 – 1098.

Huisman, M. (2009). Imputation of missing network data: Some simple procedures. *Journal of Social Structures, 10*(1), 1 – 29.

Hu, L. & Bentler, P. M. (1999) Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling, 6*(1), 1 – 55.

Jonassen, D. H. (2000). Toward a design theory of problem solving. *Educational Technology Research and Development, 48*(4), 63 – 85.

Karpowitz, C. F., & Mendelberg, T. (2014). Introduction. In C. F. Karpowitz & Mendelgberg (Eds.), *The silent sex: Gender, deliberation, and institutions* (pp. 1 – 7). Princeton University Press.

Kalkhoff, W. & Thye, S. R. (2006). Expectation states theory and research. *Sociological Methods & Research, 35*(2), 219 – 249.

Kant, V. & Kerr, E. (2018). Taking stock of engineering epistemology: Multidisciplinary perspectives. *Philosophy & Technology,* 1 - 42.

Kim, J. Y., Howard, M., Pahnke, E. C., & Boeker, W. (2016). Understanding network formation in strategy research: Exponential random graph models. *Strategic Management Journal, 37*(1), 22 – 44.

King, B. A. & Magun-Jackson, S. (2004). Epistemological beliefs of engineering students. *Journal of Technology Studies, 35*(2), 56 - 64.

Kitchener, K. S. (1983). Cognition, metacognition, and epistemic cognition: A three level model of cognitive processing. *Human Development, 26*(4), 222 – 232.

Kolmos, A. & de Graaff, E. (2014). Problem-based and project-based learning in engineering education: Merging models. In A. Johri & B. M. Olds (Eds.), *Cambridge Handbook of Engineering Education Research* (pp. 141 - 160). New York, NY: Cambridge University Press.

Kroska, A. (2000). Conceptualizing and measuring gender ideology as an identity. *Gender and Identity, 14*(3), 368 – 394.

Krivitsky, P. N. (2012). Exponential-family random graph models for valued networks. *Electronic Journal of Statistics*, *6*, 1100 - 1128.

Ladson-Billings, G. (1998). Just what is critical race theory and what's it doing in a nice field like education? In L. Parker, D. Deyhle, and S. Villenas (Eds.), *Race is…race isn't: Critical race theory and qualitative studies in education* (pp. 7-27). Boulder: Westview Press.

Ladson-Billings, G. (2000). Racialized discourses and ethnic epistemologies. In N. Denzin & Y. Lincoln (Eds.), *Handbook of Qualitative Research*(pp. 257 – 277). Thousand Oaks, CA: Sage Publications.

Ladson-Billings, G., & Tate, W. F. (2016). Toward a critical race theory of education. In *Critical race theory in education* (pp. 10-31). Routledge.

Lewis Jr., N. A., Sekaquaptewa, D., & Meadows, L. A. (2019). Modeling gender counter-stereotypic behaviors: A brief video intervention reduction participation gender gaps on STEM teams. *Social Psychology of Education, 22*(3), 557 – 577.

Louca, L., Elby, A., Hammer, D., Kagey, T. (2004). Epistemological resources: Applying a new epistemological framework to science instruction. *Educational Psychologist, 39*(1), 57 – 68.

Lopez, G. (2003). The (racially neutral) politics of education: A critical race theory perspective. *Educational Administration Quarterly, 39*(1), 68 – 94.

Mahalik, James R., Benjamin D. Locke, Larry H. Ludlow, Matthew A. Diemer, Ryan PJ Scott, Michael Gottfried, & Gary Freitas. Development of the conformity to masculine norms inventory. *Psychology of Men & Masculinity, 4*(1), (2003): 3 – 25.

Mason, L., Boldrin, A., & Giovanna, Z. (2006). Epistemological understanding in different judgment domains: Relationships with gender, grade level, and curriculum. *International Journal of Education Research, 45*(1-2), 43 - 56.

Maynes, T. D., & Podsakoff, P. M. (2014). Speaking more broadly: An examination of the nature, antecedents, and consequences of an expanded set of employee voice behaviors. *Journal of Applied Psychology*

McGee, E. O. (2016). Devalued Black and Latino racial identities: A by-product of STEM college culture? *American Educational Research Journal, 53*(6), 1626 - 1662.

McGee, E. O. & Martin, D. B. (2011). "You would not believe what I have to through to prove my intellectual value!" Stereotype management among academically successful Black mathematics and engineering students. *American Educational Research Journal, 48*(6), 1347 – 1389.

McNeill, N. J., Douglas, E. P., Koro-Ljungberg, M., Therriault, D. J., & Krause, I. (2016). Undergraduate students' beliefs about engineering problem solving. *Journal of Engineering Education*, *105*(4), 560-584.

Meadows, L. & Sekapuaptew, D. (2013). The influence of gender stereotypes on role adoption in student teams. Paper presented at the ASEE Annual Conference and Exposition: Washington, D.C.

Milner IV, H. R. (2007). Race, culture, and researcher positionality: Working through dangers seen, unseen, and unforeseen. *Educational Researcher*, *36*(7), 388-400.

National Science Foundation (2016). Science & engineering indicators. Retrieved from: https://www.nsf.gov/nsb/publications/2016/nsb20161.pdf.

Nicolazzo, Z. (2015). " I'm man enough; are you?": The queer (im) possibilities of walk a mile In her shoes. *Journal of Critical Scholarship on Higher Education and Student Affairs*, *2*(1), 18-30.

Norström, P. (2013). Engineers' non-scientific models in technology education. *International Journal of Technology and Design Education*, *23*(2), 377-390.

O'Connor, C., Lewis, A., & Mueller, J. (2007). Researching "Black" educational experiences and outcomes: Theoretical and methodological considerations. *Educational Researcher*, *36*(9), 541-552.

Ozmen, K. & Ozdemir, O. F. (2019). Conceptualisation and development of the physics related personal epistemology questionnaire (PPEQ). *Journal of Science Education, 41*(9), 1207 - 1227.

Packer, M. J. & Goicoechea, J. (2000). Sociocultural and constructivist theories of learning: Ontology, not just epistemology. *Educational Psychologist, 35*(4), 227 – 241.

Pahl, G., Beitz, W., Feldhusen, J., & Grote, K. H. (2007). *Engineering Design: A Systematic Approach.* London: Springer.

Palmer, R. T., Maramba, D. C., & Dancy II, T. E. (2011). A qualitative investigation of factors promoting the retention and persistence of students of color in STEM. *The Journal of Negro Education, 80*(4), 491 - 504.

Patton, L. D., & Bondi, S. (2015). Nice white men or social justice allies?: Using critical race theory to examine how white male faculty and administrators engage in ally work. *Race Ethnicity and Education*, *18*(4), 488-514.

Paulsen, M. B. & Wells, C. T. (1998). Domain differences in the epistemological beliefs of college students. *Research in Higher Education, 39*(4), 365 - 384.

Pawley, A. L. (2008). Chapter 3: What counts as "engineering": Toward a redefinition. In C. Baillie, A. L. Pawley, and D. Riley (Eds.), *Engineering and Social Justice in the University and Beyond* (pp. 59 – 85). West Lafayette: Purdue University Press.

Pawley, A. L. (2009). Universalized narratives: Patterns in how faculty members define "engineering". *Journal of Engineering Education, 98*(4), 309 – 319.

Pawley, A. L. (2019). Learning from small numbers: Studying ruling relations that gender and race the structure of U.S. engineering education. *Journal of Engineering Education, 108*(1), 13 – 31.

Perry, W. G. (1970). *Forms of intellectual and ethical development in college years: A scheme.* New York: Holt, Rinehart and Winston.

Prados, J. W., Peterson, G. D., & Lattuca, L. R. (2005). Quality assurance of engineering education through accreditation: The impact of Engineering Criteria 2000 and its global influence. Journal of Engineering Education, 94(1), 165-184.

Reiss, J. & Springer J. (2017). Scientific objectivity. In E. N. Zalta (Ed.), *Stanford Encyclopedia of Philosophy (Winter 2017 Edition)*, Retrieved from: https://plato.stanford.edu/entries/scientific-objectivity/.

Richardson, J. T. E. (2013). Epistemological development in higher education. *Educational Research Review, 9*, 191 - 206.

Ridgeway, C. L. (2010). Status construction theory. In J. M. Levine & M. A. Hogg (Eds.), Sage Encyclopedia of Group Processes & Intergroup Relations (p. 849 – 850). Thousand Oaks, CA: Sage Publications, Inc.

Rodriguez, L. & Cano, F. (2007). The epistemological beliefs, learning approaches, and study orchestrations of university students. *Studies in Higher Education, 31*(5), 617 - 636.

Rodriguez, D. (2010). Storytelling in the field: Race, method, and the empowerment of Latina college students. *Cultural Studies? Critical Methodologies*, *10*(6), 491-507.

Ro, H. K., & Loya, K. I. (2015). The effect of gender and race intersectionality on student learning outcomes in engineering. *The Review of Higher Education*, *38*(3), 359-396.

Ro, H. K., Merson, D., Lattuca, L. R., & Terenzini, P. T. (2015). Validity of the contextual competence scale for engineering students. *Journal of Engineering Education, 104*(1), 35 – 54.

Scheurich, J. J., & Young, M. D. (1997). Coloring epistemologies: Are our research epistemologies racially biased?. *Educational researcher*, *26*(4), 4-16.

Schommer, M. (1990). Effects of beliefs about the nature of knowledge on comprehension. *Journal of Educational Psychology, 82*(3), 498 - 504.

Schommer, M., Crouse, A., & Rhodes, N. (1992). Epistemological beliefs and mathematical text comprehension: Believing it is simple does not make it so. *Journal of Educational Psychology, 84*(4), 435 – 443.

Simpson, B., Willer, R., & Ridgeway, C. L. (2012). Status hierarchies and the organization of collective action. *Sociological Theory, 30*(3), 149 – 166.

Smith, H. L. (2019). Has nigga been reappropriated as a term of endearment? A qualitative and quantitative analysis. *American Speech, 94*(4), 420 – 477.

Solomos, J. & Back, L. (2000). Introduction: Theorizing race and racism. In L. Back and J. Solomos (Eds.) *Theories of Race and Racism* (pp. 1 - 32). New York: Routledge.

Solórzano, D. G. (1998). Critical race theory, race and gender microagressions, and the experience of Chicana and Chicano scholars. *International Journal of Qualitative Studies in Education, 11*(1), 121 – 136.

Solórzano, D. G. & Yosso, T. J. (2002). Critical race methodology: Counter-storytelling as an analytical framework for education research. *Qualitative Inquiry, 8*(1), 23 – 44.

Stanley, L., & Wise, S. (1990). Method, methodology and epistemology in feminist research processes. In L. Stanley (Ed.), *Feminist praxis: Research, theory and epistemology in feminist sociology*, 20-60.

Stempfle, J. & Badke-Schaub, P. (2002). Thinking in design teams – an analysis of communication. *Design Studies, 23*(5), 473 – 496.

Strehl, E. A. & Fowler, R. (2019). Experimental evidence regarding gendered task allocation on teams. Paper presented at the 2019 ASEE Annual Conference & Exposition, Tampa, FL.

Sweet, T. M., Thomas, A. C., & Junker, B. W. (2013). Hierarchical network model for education research: Hierarchical latent space models. *Journal of Educational and Behavioral Statistics, 38*(3), 295 – 318.

Taber, K. S. (2018). The use of cronbach's alpha when developing and reporting research instruments in science education. *Research in Science Education*, *48*(6), 1273 - 1296.

Tonso, K. L. (2006). Teams that work: Campus culture, engineer identity, and social interactions. *Journal of Engineering Education, 95*(1), 25-37.

Torres, V. (2011). Perspectives on identity development. In J. H. Schuh, S. R. Jones, S. R. Harper and Associates (Eds.), *Student Services: A Handbook for the Profession* (pp. 187 - 206). San Francisco: Jossey-Bass.

Walton, D., & Zhang, N. (2013). The epistemology of scientific evidence. *Artificial Intelligence and Law*, *21*(2), 173-219.

Wenning, C. J. (2009). Scientific epistemology: How scientists know what they know. *Journal of Physics Teacher Education Online, 5*(2), 3 - 16.

Wise, J. C., Lee, S. H., Litzinger, T., Marra, R. M., & Palmer, B. (2004). A report on a four-year longitudinal study of intellectual development of engineering undergraduates. *Journal of Adult Development, 11*(2), 103 - 110.

Wolfe, J. & Powell, E. (2009). Biases in interpersonal communication: How engineering students perceive gender typical speech acts in teamwork. *Journal of Engineering Education, 98*(1), 5 – 16.

Yu, J. H. & Strobel, J. (2011). Instrument development: Engineering-specific epistemological, epistemic, and ontological beliefs. In *Proceedings of the Research in Engineering Education Symposium-Madrid,* (1 - 8).

Yu, J. H. & Strobel, J. (2012). A first step in the instrument development of engineering-related beliefs questionnaire. In *American Society for Engineering Education.*

Appendices

Appendix A: Observation Protocol

Figure 10. Course Overview

To be completed on or prior to the first day of class.

Course Name:	Academic Level:	Enrollment:
Term: FA WN SP/SU	Term Dates:	Project Name:
Instructor(s):		
Course Components:	☐ Lecture	☐ Discussion ☐ Lab

Lecture Room: Lecture Day/Time: Lecture Instructor(s):	Image/Description of Lecture Space:
Discussion Room: Discussion Day/Time: Discussion Instructor(s):	Image/Description of Discussion Space:
Discussion Room: Discussion Day/Time: Discussion Instructor(s):	Image/Description of Discussion Space:
Lab Room: Lab Day/Time: Lab Instructor(s):	Image/Description of Lab Space:

<u>Classroom Observation Form</u>

Figure 11. Classroom Observation Form

To be completed during full class activities.

Course Identifier:	
Date, Day, and Time of Observation:	
Course Component (Circle One): Lecture Discussion Lab	
Instructor(s):	
Class Attendance: Do there appear to be students absent from the class session?	
Description of Classroom Activities:	
Describe the extent to which instructors, IAs, lab managers are involved in the activity.	
Engineering Epistemology	**Describe**
How does the instructor, lab manager, etc. discuss objectivity in knowledge creation or evaluation with students?	
How does the instructor, etc. discuss neutrality (e.g., value-neutrality, moral neutrality) in knowledge creation?	
How does the instructor describe engineering practice (e.g., design practice, engineering teamwork, engineering work)?	
How do the students discuss objectivity in knowledge creation or evaluation with students?	
How do students discuss neutrality (e.g., value-neutrality, moral neutrality) in knowledge creation?	
How do the students discuss objectivity in knowledge creation or evaluation with students?	
How do students discuss neutrality (e.g., value-neutrality, moral neutrality) in knowledge creation?	

Team Observation Form

Figure 12. Team Observation Form

To be completed during team observations

Team Identifier:	
Team Members Present:	
Description of Team Activities (Describe the possible performance outputs afforded to students):	
Are activities:	☐ Design ☐ Tech Comms ☐ Building
Action Opportunities:	**Describe:**
In what ways does the team delegate action opportunities (e.g., tasks)? How does the team delegate AOs?	
In what ways do students try to appropriate or avoid particular tasks on the team?	
Performance Outputs:	
In what ways do students recognize particular performance outputs?	
In what ways do students ignore/fail to acknowledge particular performance outputs?	
Do students malign particular performance outputs?	
Performance Evaluations:	
How do students offer explicit performance evaluations in their teams?	
How do students offer implicit performance evaluations in their teams?	
How do other actors offer performance evaluations to individuals or the team (e.g., IAs, instructors)?	
Influence:	
In what ways do students try to exert influence over individual and team behaviors? Are they successful?	
In what ways do students show deference to influential	

teammates, instructors, IAs, etc.?	
In what ways do students seem to control information flows on the team (e.g., *who* asks *what* questions and *how*)	
Epistemic Cognition	
In what ways do students describe the source of their ideas/actions during activities?	
What sources of knowledge do students draw on to describe and defend their ideas?	
How do students resist particular ideas/actions during team activities?	
What sources of knowledge do students draw on when resisting particular ideas?	
If applicable, do students articulate the source of their differing ideas?	

Appendix B: Semi-Structured Design Experience Interview

Thank you for agreeing to participate in an interview about your experiences so far in ENGR 100 ROV course. During today's interview, I want to focus on your team's design process, including how you thought through particular design challenges and made particular design decisions.

As a reminder, your participation is completely voluntary. If you would like to stop, you may end our interview at any point. If I ask you a question that makes you uncomfortable, you can let me know. We can skip that question, stop the interview, or do whatever makes you comfortable.

Do you have any questions before we begin?

1. Has your experience in ENGR 100 been generally positive or negative so far?
2. I want to talk a bit about your individual ROV design. Can you talk me through your individual ROV design?
    a. What are the major components?
    b. What was your custom part?
        i. What was it designed to accomplish?
        ii. Why do you think this design would work?
    c. I am particularly interested in the things students draw on when they are solving engineering problems. For example, some people draw on prior experiences, cultural beliefs and practices, or engineering coursework, to name a few.
        i. What ideas did you draw on?
        ii. Did you use these same ideas when explaining your individual design to your team?
            1. If yes: How did your team respond to your explanation?
            2. If no: What types of ideas did you draw on to explain your design to your team? How did your team respond?
    d. Now I want to discuss your team's ROV design. Was there any component of your team's design that came from your individual design?
        i. Why did your team decide to use this component?
        ii. Did you have to convince them that this component would "work"?
            1. **If yes:** How did you convince them?
            2. **If no:** Why do you think your team was already convinced the component would work?

iii. Were there any components of your individual design that your team rejected or did not consider?
1. **If yes**: Why do you think they opposed the idea?
2. **If no:** Did your team decide to build your individual design? Were there any additions to your individual design?
a. In general, did your team rely heavily on your ideas?
i. **If yes:** Why do you think that is?

e. Describe your team's custom part.
i. How did your team come up with this custom part?
1. What were your team's priorities when deciding on a custom part?

ii. What is the design problem it is supposed to address?

3. Were there any "big" debates (besides the debates about your individual design) on your team about particular design decisions?
a. **If yes:** Can you describe your position during that debate.
i. Why did you hold that opinion?
ii. What did your team decide? Did your idea win over, or did you go in a different direction?
1. If student's idea **was** selected: Why do you think your team eventually settled on your idea? How did you (or others on the team) convince people who disagreed with you?
2. If student's idea **was not** selected: Why do you think your team rejected your idea?
a. Did you change your mind on the idea?
i. **If yes:** How did your team convince you to support the other idea?
ii. **If no:** Why do you think you were unsuccessful in convincing your team to select your idea?

b. **If no:** Why do you think your team had such broad consensus on your ROV design?
c. **Repeat this process (given time):** Were there any other debates your team had about your ROV design?

4. Now I want to talk about your experiences working with your team.
a. There were a number of tasks outlined by your instructors for completing the project, including technical communications tasks (e.g., recording ROV data and producing reports about the ROV), design tasks (e.g., designing the controls system and building the CAD model of the ROV), and building tasks (e.g., fabricating the custom part and building the ROV).
i. What were the tasks you contributed to the most?
ii. What were the tasks you contributed to the least?
iii. How did your team manage how tasks were delegated?

        iv. Were there tasks that you wanted to contribute to that you rarely, or never, got around to doing?
            1. **If yes:** Why?
        v. Were there tasks you were not particularly interested in doing, but that you took on for the team?
            1. **If yes:** What made you want to avoid these tasks?
            2. **If yes:** What made you take these tasks on?
5. In general, how comfortable did you feel when sharing ideas on your team? Engaging in debates about your ROV?
    a. What made you feel that way?
    b. **If uncomfortable:**
        i. What makes you feel uncomfortable?
        ii. Can you describe a time when you wanted to share an idea, but you did not?
6. In general, do you feel like your team acknowledged and considered your ideas while you were making decisions?
7. Was there ever a time when you thought your social identities (e.g., gender, race/ethnicity, socioeconomic status) had an effect on how you or your work was perceived in your team? If yes, please tell me about one of those times.
8. What, if anything, did you learn about how to present your ideas in engineering in general during your ENGR 100 experience?
    a. Can you describe a time during which you felt this was particularly important?
    b. Did you use other approaches to present your ideas (e.g., analogies, your own cultural experiences)?
        i. Can you describe what you did and how that was received?
9. In general, what would you say you learned about important values in engineering as it relates to engineering design work this semester?
10. What went well for you in ENGR 100 and in your team specifically?
    a. What challenges did you face in ENGR 100 or in your team specifically?
11. Is there anything else you would like to share about your experiences in ENGR 100 that we have not already discussed?

Appendix C: Peer Mentor Journal Prompts

We are asking you to write brief reflective journals about your time as a peer mentor in ENGR 100. Below are five journal prompts that we hope will guide your reflection as you write. You are **NOT** expected to respond to each bullet point (though you may if you see fit). Instead, the bullets are meant to draw your attention to particular characteristics or experiences of interest.

As a reminder, your participation in this research is completely voluntary. You are free to skip any, or all, of the question in this journal submission.

If you have any questions, please email **Trevion Henderson** at tshend@umich.edu.

Briefly describe your interactions with the team so far. • Who communicates with you (e.g., the entire team, an individual)? • What questions is the team asking you? • What types of design advice have you given them?
In general, does the team appear to be working well together? • Describe any conflicts you have noticed in the teams and how, if at all, they have been resolved. • Do students provide feedback (either negative or positive) to each other?
Are there any students who appear to be doing more of the (a) design work, (b) building work, or (c) technical communications work? Why do you think this is the case? • Describe how the team appears to delegate tasks.
Describe any design, building, or communication challenges the team is facing. How is the team attempting to address these challenges? • Is any student taking the lead on addressing these challenges? • Are there any students who do not seem as involved as the rest of the team in addressing challenges during the project?
We are particularly interested in how the team decides to pursue, or discard particular ideas. • Have you noticed any patterns of influence on the team (e.g., the team spends more time on one students' ideas, the team does not recognize a particular student's contributions)?

- Do women and students of color appear to exert equal influence in team decision-making?

Appendix D: Beginning-of-Term Survey

In this survey you'll answer questions about yourself and your opinions. Your answers will help Tandem give special advice just for you.

You will get credit for completing this survey and it can be seen by the $Course team, but your responses will not impact your grade in any way.

Please answer honestly and take time to think about the questions.

Please indicate the degree to which you agree or disagree with each of the following statements about engineering.

[Beliefs about Engineering Knowledge]

1. [BT_EngrBelief_1] Engineers should rely on math and science when defending their ideas
2. [BT_EngrBelief_2] In engineering, first-hand experience is as valid a source of knowledge as knowledge established by experts.
3. [BT_EngrBelief_3] Math and science are the best ways to defend ideas in engineering.
4. [BT_EngrBelief_4] If engineers follow mathematical and scientific principles, they will always find the best solutions.
5. [BT_EngrBelief_5] Engineers should rely on math and science when communicating their ideas.
6. [BT_EngrBelief_6] Knowledge in engineering can always be proven true or false.
7. [BT_EngrBelief_7] Knowledge in engineering is objective.
8. [BT_EngrBelief_8] Knowledge based in math and science is the most valid form of knowledge in engineering.
9. [BT_EngrBelief_9] Theories in engineering cannot be argued or changed.
10. [BT_EngrBelief_10] Interpretations of engineering knowledge should not change from person to person.
11. [BT_EngrBelief_11] Technical problems in engineering have only one right answer.
12. [BT_EngrBelief_12] Engineers should leave their personal beliefs out of their engineering work.

13. [BT_EngrBelief_13] Social justice concerns should not influence engineering work.
14. [BT_EngrBelief_14] Political beliefs should not influence engineering work.
15. [BT_EngrBelief_15] Cultural beliefs should play no role in the creation of engineering knowledge.
16. [BT_EngrBelief_16] Engineers should leave their personal opinions out of their engineering work.
17. [BT_EngrBelief_17] Human emotions should play no role in engineering work.
18. [BT_EngrBelief_18] Engineers should leave their cultural beliefs out of their engineering work.
19. [BT_EngrBelief_19] Engineering knowledge is value-free.
20. [BT_EngrBelief_20] Political beliefs should not influence solutions to real-world engineering problems.

Appendix E: Group Communication Network Survey

Group communication check

You've made a few group decisions in the last week. Some decisions might feel like they hold a lot of weight, like how your ROV design could impact your learning or grade. Some might also feel personal, like how many of your ideas were chosen by the group.

About this survey:

- It takes 10–15 minutes to complete, so make sure you have time before starting.
- This survey asks about how your team has been communicating and making decisions in these first meetings.
- Your teammates cannot see your answers.
- You get credit for completing this survey, but **your responses will not impact your grade or your teammates' grades.**

[SECTION -- conversation team eval; class type=task]

How each person contributes

There are many valuable ways to contribute to group design conversations and decisions. You and your teammates probably have unique contributions, such as generating a lot of ideas, posing questions, or listening.

How much did you and each of your teammates:

[side by side matrix - 5 (1) Never (2) Rarely (3) Sometimes (4) Often (5) Always]

- [EC_Contribute] Contribute new ideas or perspectives

[Section - Help]

Who has helped

For these questions, think about when **<u>you</u>** (not your teammates in your stead) have consulted with instructional staff during your work in ENGR 100. This may have occurred before, during, or after class, in office hours, or at any other time.

[EC_HelpTech] Who, if anyone, did you consult to ask technical questions about your ROV design?

- ❏ ENGR 100 Instructor [Name blinded for Proposal]
- ❏ ENGR 100 Undergraduate Assistant [Name blinded for Proposal]

❏ Your team's peer mentor

❏ None of the above

[EC_HelpProp] Who, if anyone, did you consult to prepare your individual design proposal?

❏ ENGR 100 Instructor [Name blinded for Proposal]

❏ ENGR 100 Undergraduate Assistant [Name blinded for Proposal]

❏ Your team's peer mentor

❏ None of the above

[EC_HelpReview] Who, if anyone, did you consult to prepare for your team's most recent design review (i.e., PDR, CDR or DDR)?

❏ ENGR 100 Instructor [Name blinded for Proposal]

❏ ENGR 100 Undergraduate Assistant [Name blinded for Proposal]

❏ Your team's peer mentor

❏ None of the above

[EC_HelpConflict] Who, if anyone, did you consult to manage team conflicts?

❏ ENGR 100 Instructor [Name blinded for Proposal]

❏ ENGR 100 Undergraduate Assistant [Name blinded for Proposal]

❏ Your team's peer mentor

❏ None of the above

[EC_OutsideHelp] Good feedback or advice might come from students outside of your ROV team. Your instructors would be glad if you sought out help. Did you work with any students outside of your team (e.g., from other teams, outside of this course) on your most recent ROV design assignment (e.g., PDR, CDR, or DDR)?

- Yes
- No

[SECTION - WhoHelp]

Who helped?

Remember, your instructors think getting help from other students is a good practice! We are asking to better understand how students are getting help.

[If Yes EC_WhoHelp]: Please list **first and last names** of any students beyond your team with who helped with your most recent ROV design assignment (e.g., PDR, CDR, or DDR)?

Appendix F: Midterm Network Survey

Where would you place [teammate] on each of these scales? [5 Point Scale]			
Enact contributions	Many of Daniel's ideas were used in our project.	←→	Our project didn't include many ideas from Daniel.

[SELF]

Where would you place yourself on each of these scales? [5 Point Scale]			
MT_Self_Enacted	Many of my ideas were used in our project.	←→	Our project didn't include many of my ideas.

Appendix G: Dissertation Codebook

Table 14. Dissertation Codebook

Code	Description	Example
Background Characteristics		
Salience of Race	Student discusses the salience of race in engineering or engineering design.	And then when it asks you race, I always sort of feel like in the back of my head like, "Okay, I'm not, I'm going to get like less considered because I'm Asian," because there's just...It's almost like we turned into the opposite of a minority, I feel like in the engineering realm at least.
Salience of Gender	Student discusses the salience of gender in engineering or engineering design.	I think that she might've thought as me trying to talk over her because she's a woman in engineering and historically they might not be treated to be at the same regard. I think she was very aware of that, where I wasn't as aware of like, it's not something that I was trying to do.
Engineering Background Experiences	Student discusses engineering-related background experiences.	I've been thinking about this a lot a lot with respect to Engineering 100 and 101. I took two years of CS in high school. I feel no confidence in my CS skills.
Inexperience/Lack of Skills	A student discusses their lack of experience, and the role inexperience played in their individual or team design process.	Well, I guess I feel like for a student that doesn't have a ton of experience, it's all just stuff that you might just see in passing. I feel like everybody's seen like a picture of an ROV in some documentary movie just in passing, even if they haven't really paid attention to it or just like any... I think that all the ideas come from just the back of the mind after you happened to just see something early in your life and don't even notice it.
Confidence	A student discusses the degree to which they are confident taking on design, build, or communicate tasks. **Note:** I distinguish this from comfort.	Definitely grown in those areas, but definitely not confident enough to do a lot of it by myself. Having the experience from my team members definitely helped me in the project and helped the team get everything together so quick. If everybody on the team had my level of experience in using tools and putting everything together in the lab I'm sure we would not have been the first team to assemble the ROV.
Personal Background Experiences	Student discusses non-engineering-related background experiences.	It's funny. I always tell people because I literally live in the middle of a cornfield and my family's farm is a half a mile through the woods behind my house. And we have a Bring Your Tractor to School Day.
Interpersonal Relationships		

Positive Interpersonal Relationships	Student discusses positive interpersonal relationships in their team.	I definitely think there was, and I think that has to do with the fact that Lauren and Stephanie, they'd been sitting next to each other in class before and had known each other. It could have been the fact that they just both happened to be girls who already knew each other and therefore were friends, so they had a different dynamic than us three guys over, like Rehman, Danish and I, who didn't really know each other as much.
Negative Interpersonal Relationships	Student discusses negative interpersonal relationships in their team.	I feel like Addy in the beginning gave kind of a bad impression. Our first group meeting she wasn't really paying attention and I think the class after that she was like 40 minutes late. Personally, I try to avoid I think conflict based on my emotions. If it's not tantamount to my grade then I just kind of avoid it, so I never really talked to her.
Trust	A student describes a degree of trust in another teammate, particularly related to trust in their work/contributions on the team.	Yeah, I think I trusted everyone and sense that they would do quality work. And I think I'd had a little bit too much trust recently in the CDR report.
Distrust	A student describes a degree of distrust in another teammate, particularly related to trust in their work/contributions on the team.	But we recently went over that and fix it for the design report. Other than that, I think Kevin did not have a lot of trust in Addy, and that kind of created me somehow mediating between that, which I'm not really sure why that was necessary.
Conflict Resolution	A student describes the resolution of a general or specific interpersonal conflict that occurred on the team, wither between individuals, or across the team as a whole. **Note: Design decisions are <u>not</u> generally considered the resolution of conflicts.**	And I think that that was also when Stephanie and I were having, I won't say issues, but when we were arguing to begin with, I think that she might've thought as me trying to talk over her because she's a woman in engineering and historically they might not be treated to be at the same regard. I think she was very aware of that, where I wasn't as aware of like, it's not something that I was trying to do.
Conflict	A student describes a general or specific interpersonal conflict that occurred on the team, wither between individuals, or across the team as a whole. **Note: Design disputes/debates are <u>not</u> generally considered conflicts.**	I think for me, I guess it was just our group I think had different ways of working on things. And so when you're used to working on individual projects or working just basically on your own and following your own timeline, where I like to get things done early just so I can knock them out, and so I can feel like I'm ahead of the curve in case something comes up, where other people might be more inclined to wait till the, I won't say last minute but not as soon as I would like to get it done.
Comfort	A student discusses their comfort with participating in team	And especially once I started to get more comfortable with them and I actually felt like I've started to contribute, I just started to feel much more comfortable around them and starting to speak my mind, to offer my opinion on things. And I think

	activities (e.g., sharing ideas, challenging teammates).	things just got better as the term went on. I just started to do more. I felt like I was actually contributing, especially once I got started on the CAD model and I thought I started to do much better overall.
Discomfort	A student discusses their discomfort with participating in team activities (e.g., sharing ideas, challenging teammates).	I think it's just because, like I said earlier, I just wasn't familiar with my teammates, especially considering that they all seem to know each other so well or that's at least what I thought. And so I just talked to some people about it and they told me to give it a chance, and so I did.
Prior Relationship	A student discusses how relationships (i.e., between teammates) prior to the course played a role in the design process.	I don't think I really had any arguments with my teammates about anything, if I can remember correctly. So I think we got along pretty well. And so yeah. It worked out.
Team Communication	A student discussion the role of communication on the team, particularly as it relates to the ease or difficulty of communicating ideas to teammates.	And in terms of sharing the ideas that weren't necessarily ours, I think that it worked fine, but I think that also during the presentation there were a few times where we stepped over each other to say, "Oh, I thought we were doing this." There was communication but maybe a little bit flawed communication just as everybody gets the same amount of information but then maybe extrapolates a little bit more based on their own biases or their own idea about how the project should go.
Conflict Avoidance	A student discusses making a decision to avoid conflicts on the team.	Addy wasn't at our meeting and Max, I think he was probably going to side with Chelsea, although it was only a little bit. It was mostly neutral so it was basically me arguing my own design versus Chelsea arguing her own design. One of us had to give eventually and I didn't want to [pause] ... As long as I got to build and drive it around a little bit, even if it wasn't at the competition, I didn't really mind giving up my idea to build someone else's because I know that when you suggest an idea and can invest time in it, it really hurts to just be outvoted and for the team just to go a different direction when you've already invested in one idea…So I just decided to drop it.
Status Construction		
Action Opportunity		
Action Opportunity Taken	A student appropriates an opportunity to contribute to the team (i.e., without consent of the team).	Well, a lot of the times... okay, Matt would go over my work every time. I don't think I've written one section that he hasn't redone completely. Or with the control box that I designed, he just redid the whole thing. I was really frustrated with that because it's not like... he just changed the colors. And I don't know. I feel that's really condescending to be like, to not think that I can handle the work myself.

Action Opportunity Granted	A student is granted the opportunity to contribute to the team (i.e., with consent or in negotiation from other team members).	I wanted to work a little bit more on the CAD design like I had mentioned earlier. But then, I don't know, that kind of turned into Cam's thing that we were kind of just all in agreement that he would work on that.
Action Opportunity Avoided	A student rejects, or seems to avoid, a particular task or opportunity to contribute to the team.	Ryan was the only student to explicitly reject participating in the control box, and he was immediately relieved of the responsibility.
Action Opportunity Denied	A student attempts to take an action opportunity, but is denied the opportunity to contribute by one or more teammates.	Stephanie became exceptionally frustrated by the interruption, and I heard her mumble, “I guess I won’t get to finish a sentence.” She later expressed similar frustration when Rehman was explaining his idea about the placement of the t-joint.
Action Opportunity for Design	A student is granted, or takes, the opportunity to contribute to design (e.g., CAD) tasks for the team.	I just started to do more. I felt like I was actually contributing, especially once I got started on the CAD model and I thought I started to do much better overall.
Action Opportunity for Building	A student is granted, or takes, the opportunity to contribute to build tasks for the team.	Though he was assigned work with Lauren and Stephanie to build the frame, Danish spent a great deal of the session working on the control box alone.
Action Opportunity for Technical Communications	A student is granted, or takes, the opportunity to contribute to technical communication (e.g., report writing) tasks for the team.	[Student] really stepped up in making sure that the reports were done on time and getting people to plan when they were going to meet and who was working on what.
Supervised Action Opportunity	A student is granted an action opportunity to contribute to the team, but that opportunity is supervised/controlled by another student.	Kyle and Seth agreed that their changes did not change the shape of the ROV a great deal, and that the coefficient of drag would like be very similar. Kyle proceeded to tell Seth how to represent this decision not to do new calculations in his writing. Kyle: I would just explain that in the calculations. Like… we haven’t significantly changed the shape of the ROV moving forward, and now that we are using two thrusters instead of one to surge, it will have a new velocity that we calculated using the coefficient of drag that they came up with.
Performance Evaluation		
Positive Performance Evaluation from Teammate	A teammate provides a positive performance evaluation in one of the focal teams.	Kyle approved of the new logo—“that looks sick”—and later approved of the changes to the slides—“Everything looks good to me…”
Negative Performance Evaluation from Teammate	A teammate provides a negative performance evaluation in one of the focal teams.	As the team was giving self- and peer-feedback after the first run, one consistent piece of feedback was that they were to harsh about their own ideas. Danish asked that they all agree not to lead with negatives.

Positive Performance Evaluation from Peer	A peer outside of a focal team provides a positive performance evaluation in one of the focal teams.	(From student written feedback): Thruster guards. Meant to improve the reverse thrust. The idea of the guard appears to be very smart. However, I think the design needs more elaboration because the thrust overall will be decreased and there will be a lot of turbulence.
Negative Performance Evaluation from Peer	A peer outside of a focal team provides a negative performance evaluation in one of the focal teams.	Kyle proudly said they only used class time, to which [student] responded, "well you all have really simple designs." [Note: I'm interested that this appeared to be a masculinity contest, and [student's] comment seemed meant to belittle their accomplishment.]
Positive Performance Evaluation from Authority	An instructor or peer mentor provides a positive performance evaluation in one of the focal teams.	When they return to the lab and hold a short debrief, [peer mentor] reiterates that the team has cool ideas, "the coolest I've ever seen", but also the ideas are likely to be the most challenging.
Negative Performance Evaluation from Authority	An instructor or peer mentor provides a negative performance evaluation in one of the focal teams.	Paul noted that the team was criticized for a lack of innovation in their preliminary designs, saying, "I feel like they were ripping on us pretty hard." As a result, the team takes turns discussing ideas to improve innovation in their designs.
Implicit Performance Evaluation	A student signals disapproval of an idea or performance output without saying so directly. These include actions such as redirecting the conversation away from an idea, changing work without the contributor's knowledge, etc.	While explicit evaluations were rare, implicit evaluations occurred throughout the conversation in the form of redirection (i.e., to or away from particular ideas – see the John and Kyle examples above) or the collective decision to see some ideas through.
Response to Feedback	A student describes how they responded to negative or positive feedback during the design process.	But I thought that the feedback we got was very helpful for it and it actually inspired changes pretty quickly for us, where I can imagine the individual change memo, if some teams were happy with their design before the DDR that it might have been hard to come up with that, but that was one of the easiest projects I had for this class was the change memo.
Negative Self Evaluation	A student offers a negative evaluation of their own work to the team.	I noticed a few times when students preemptively evaluate themselves before presenting ideas to the team. For example, before showing his Google Drawing, Matt prefaces with "It is completely awful!"
Influence		
Influence by Questioning	A student exerts influence over the team through the use of questions.	Later, as I chat with Heather about Team Mobula's PDR, Heather noted a familiar tactic from Chelsea—the use of negatively framed questions about particular designs in order to position the design she prefers as the best choice.
Influence by Organization	A student exerts influence over the team by organizing the team's conversation or ideas.	The team started the session by bouncing around topics. Stephanie grew frustrated by this, and eventually stopped the discussion—"Wait, can we table

		that?"—to create a To Do list for the meeting. Stephanie listed three items: Assign CDR jobs, decide nose cone, timeline.
Influence through Apparatus of Communication	A student exerts influence through control of the apparatus of communications.	Again, I notice that Kyle's control over the apparatus of communication gives him some authority on the team as I notice (a) everyone's contributions to the discussion must implicitly be signed off by Kyle for it be documented, (b) Kyle controls how ideas are represented in the documentation, and (c) his ideas need not be approved by, or even mentioned to, the team to be documented.
Influence Over Task Delegation	A student exerts influence over the ways in which tasks are delegated.	With only Kyle and John present, the two begin to decide on the major tasks for the report. This is interesting because Kyle proposed splitting tasks in a way that was different than what I saw in Team Surge. Whereas Team Surge decided to split by the major bullet points, Kyle offered that at least one bullet point should be divided (the feedback and sketch that is required). The two agreed to this, and it appears this plan was never changed or re-addressed when the rest of the team arrived.
Unilateral Decision	A student makes a unilateral decision for the team.	The team is relying on the CAD model to communicate their design to [IA] and [instructor]. Thus, Cam's unilateral decision to restart the CAD model means the team will not begin building today (though there was no pushback from the team).
Decision by Negotiation	The team makes a collective decision (i.e., rather than an individual leading a discussion).	Later, when Lauren is at the white board sketching ideas, she uses her sketching to redirect the conversation—the team began discussing thruster placement. This is effective, and Rehman joins her at the board to began negotiating ideas about thruster placement (e.g., "What if we moved X?").
Influence by Leading Discussion	An individual leads the team discussion. Sometimes this is physical (by standing in front of the team, commandeering the apparatus of communication). Other times this is perception (i.e., by organizing the team's discussion). I expect overlap in other categories.	Kyle appears to take the lead in the initial design discussion. As the discussion progresses, he stands and approaches the white board near the monitor as the team discusses ideas.
Influence by Answering Questions	A student exerts influence over the team's design process by answering design questions.	Still, a second way that information flows were controlled was through the asking of questions. While Kyle commandeered the board, it was both Kyle and Paul who communicated with me the most. This was due, in part, to the way I problematized ideas in general. As students presented ideas to the teams, I would ask questions to get them to elaborate on ideas, or consider things they clearly had not considered (e.g., "how are you going to attach that).

Influence by Exclusion	A student or students exerts influence over the team's design process by excluding, either purposefully or by circumstance, other members from team activities.	Kyle appears to take the lead in the initial design discussion. As the discussion progresses, he stands and approaches the white board near the monitor as the team discusses ideas. Paul joins Kyle multiple times at the white board as they discuss ideas [Note: This leaves them physically facing away from the team as they discuss ideas at the board, though they do occasionally turn to address the entire team].
Influence by Fixation	A student or students exerts influence over the team's design process by fixation--essentially insisting on or refusing to discard an idea. Often, students make sense of this by saying someone was "the loudest" or "most vocal" person in the room. However, other times this was articulated as someone's persistence being "not worth the argument."	Lauren and Danish on the other hand compared to us were much more, I won't say pushing, but much more interested or excited for their design. So rather than, I guess make an argument where there didn't necessarily need to be one when three of us didn't really have strong feelings towards our ROV, it might've been easier just to put those two together as opposed to trying to make a completely new thing from scratch that maybe they wouldn't be as happy with.
Influence by Elevation of Eurocentric Epistemologies	A student or students exerts influence over the team's deign process by adhering to Eurocentric epistemologies--elevating technical knowledge, scientific objectivity, neutrality, etc.	I was surprised by how explicit people's feelings about ideas were laid bare during the meeting. For example, Lauren explicitly articulated, "I'm just not into the trapezoid." [Note: Interestingly, when the argument began about this, Lauren struggled to articulate a technical reason against the trapezoid frame. Danish took to the board to provide a technical reason for the frame. Somehow, Danish won out here.] "Noooooo!" –Ryan (re: the fish design).
Epistemic Cognition (in team/individual discussions)		
Use of Technical Knowledge	A student relies on technical knowledge while discussing ideas.	However, when Lauren suggested it "is more hydrodynamically stable", Danish pounced on the use of technical terms to describe a benefit of the design. He quickly seized on the comment and began to write out (seemingly arbitrary) mathematics concepts on the board to push the team back toward the trapezoid design.
Use of Non-Technical Knowledge	A student relies on non-technical knowledge while discussing ideas.	The only times I was really technical, I think was when I was defending something, or advocating for something which was being fought against, in terms of design. Like if I was trying to get some kind of reasoning as to why this was better for design than the other thing, then I would try and be more technical about it, get something more discreet.
Use of Prior Experience	A student or team references prior experiences to support an idea during a design discussion.	At times, students relied on prior experiences to elaborate and defend ideas. For example: Matt: Remember in the lab when it was way faster to turn when the thrusters were further apart? Chelsea: Yeah, we should definitely do that with the surge thrusters! Keep them far apart.

Elevation of Technical Knowledge	A student or team elevates technical knowledge during their discussion of ideas.	John offers one approach to improving their team's innovation. As students discuss ideas, John offers, "I think we need to do some calculations. We need to do some math, boys, otherwise we don't know what the hell we're doing."
Elevation of Non-Technical Knowledge	A student or team elevates non-technical knowledge during their discussion of ideas.	Later during the discussion of the cone idea, Danish expressed confusion about Ryan's description of the cone idea. "Think ice cream cone!" (Stephanie) Ryan laughed at Stephanie's explanation—"I can't believe you just said that. That's exactly what I said last time."
Rejection of Technical Knowledge	A student or team rejects ideas based in technical knowledge.	Later in the meeting, Dan stopped the team to tell them they have a problem. According to their work in solid works, "the force of gravity is significantly greater than the buoyancy, so we're sinking." There was a long discussion on the team about how to address this. They start by suggesting his calculations might be wrong. [Note: This is interestingly similar to the issue between Addy and Kevin—the assumption that the calculation must be wrong if it means my idea is bad.]
Rejection of Non-Technical Knowledge	A student or team rejects ideas based in non-technical knowledge.	As the team began reviewing center calculations, Addy began to discuss the slide with the team to a slew of concerns from her teammates. Addy began to defend her calculations, drawing heavily on technical knowledge to defend her work. In particular, she expressed a concern that her calculations suggested the ROV would pitch and perhaps roll. To defend this assertion, she began to describe the relationship between the centers of gravity and buoyancy and how she developed the work on the slides. This, however, did not seem to convince the team.
Distrust of Technical Knowledge (Is this different than Rejection of Technical Knowledge?)	A student expresses skepticism about work based in technical knowledge.	Seth: The thing is, they did it based off of their thrusters, but the thrusters they found only had like 22.4 Newtons, so their thrusters weren't that different from the original thrusters, and when I calculated it from their original values I got like 80 Watts. Can one of you guys just make sure I didn't do something dumb? I was interested, again, in this assumption about numbers and whose work is correct. The distrust of their own work is interesting, particularly given that they have openly recognized that it is the other team's work that makes little sense to them.
Allusion to Mathematic or Scientific Language	A student alludes to, but does not cite or use, scientific knowledge	The argument about the yaw thrusters followed a similar pattern for John: (a) present an idea, (b) after it is not embodied on the team, "scientize it" (or at least allude to scientific knowledge). Both the argument about whether to have sway thrusters, as well as the argument about place of yaw thrusters followed a similar form.
Rhetorical Shift	Student presents an idea using multiple arguments, ideas, or sources of knowledge.	John's resistance to sway thrusters takes on a number of forms before he is finally able to get the team to somewhat agree. First, he just explicitly articulates his opposition to sway thrusters as "unnecessary." Next, he took to the board to sketch an ROV, arguing for why sway thrusters would not be necessary. During his work at the board, John asked the team to consider both "sway vs. no sway", articulating the issue as a design dilemma. Third, he rearticulated the argument in terms of the

		technical aspects including sway thrusters might entail, saying that the sway thrusters "increases the complexity of the design and requires way more math."
Deference to Authority	Team or student relies on advice from authority figures (e.g., peer mentor, instructor) to make a design decision.	For example, Paul noted that the team was criticized for a lack of innovation in their preliminary designs, saying, "I feel like they were ripping on us pretty hard." As a result, the team takes turns discussing ideas to improve innovation in their designs.
Guesswork	A student supports and idea or work with guesswork.	What about adding the float, too, because we never really specified how we wanted to solve that, and in the end, we just kinda threw something on.
Use of Intuition	A student offers an idea that is based on intuition.	There are times when the team must defend their position on particular aspects of their design. For example, Heather asked about their two innovations, and some of the potential drawbacks. Max, in discussing the "fin" innovation responded, "I don't know much about the hydrodynamics or the physics behind it, but I do think the fin will help with stability." [Note: Here I am suggestion Max relied on intuition about the innovation rather than technical knowledge, yet he still tries to articulate the idea using the technical knowledge from the class.]
Source of Idea	A student discusses the source of their individual or team design ideas.	Then using that, I sort of just looked up a bunch of ROVs that are commercially available. More like recreational ROVs that just have cameras on them and I sort of used those to figure out what the best thruster placement was and why they put thrusters where they did.
Idea Taken Up	A student discusses and individual or team idea that was taken up (e.g., heavily discussed, utilized in the design process). Note: Not all ideas that are "taken up" are utilized in the final design. Some are considered but later discarded. This code is about initial responses and reactions to ideas.	I think most of my ideas were kind of similar to what our team ultimately came up with. Just a simplicity, the frame itself is, that I came up with, it was pretty similar to what we ended up choosing. Just a rectangular shape with four thrusters for direction and... For movement and for directions.
Pushback	A student discusses an idea that it not taken up by the team but is also not summarily discarded. **Note: I distinguish this from the "idea discarded" code below.**	A number of ideas were maligned throughout the discussion. Kyle put forth ideas for thruster placement, which were not supported by the team. Still, Kyle did not cede the point, and he spent considerable time at the board drawing the idea. He drew at least two examples arguing for his thruster placement ideas.
Design Priority	A student discusses design priorities (e.g., maneuverability, sustainability) OR a student discusses ideas that were **not**	But then they argued that having them out on the outside would be... Would offer more of a gain of maneuverability, which I just didn't put as much priority in or I guess I didn't realize what the benefit of having them out on the outside would offer as much as maneuverability.

	priorities in their individual or team design.	
Idea Discarded	A student discusses and individual or team idea that was discarded (e.g., rejected by a teammate, never considered).	Stephanie began to challenge the “trapezoid” frame, and questioned the benefits of the frame. At one point, she proposed a “fish” shaped frame and began to sketch the idea on the board. This idea was immediately rejected. Rehman: Whaaat!? WHAAAT!? Ryan: Nooooooo!
Role of Technical Tools	A student discusses the role of technical tools in their design work, such as the role of CAD models in their discussions.	That was one of the most, I think important things of the CAD model is just finally being able to say, "Here you can see every single side, you can see it from several different aspect ranges or you can see it from diagonal top, or behind, or underneath." So being able to actually have a realistic model as opposed to drawing boxes was important to getting the team on the same page.
Constrained by Technical Knowledge	A student or team discusses how adherence to mathematics or science constrained their ideas (e.g., led to them to discard particular ideas.)	Yeah, so I think the first problem really was that I didn't understand that you could cut the PVC dimensions. So everything in there is like the way it is because I thought it had to constrain to three and a half or seven or 11. So that was problem number one, and that's why the design turned out the way it is. But yeah, I think a lot of it was just thrown out the door because I didn't realize what the true constraint story, I don't know if I answered your question or not.
Rejection of Authority	A student or team pushes back or altogether rejects the input of authority (or Authority) in their design decisions.	[Note: I recall having a conversation with Kevin about this idea earlier in the semester. Heather and I told him we thought this idea was unlikely to work for various reasons. It’s interesting that he convinced the team using the “Hey, look! Someone else did it before!]
Engineering Related Beliefs		
Epistemic Tension	An actor (i.e., student, instructor, mentor) expresses tension between dominant epistemologies in engineering and their own perspectives.	Today the class discussed weighted decision matrices. Heather began with, “You are all engineers, and my sense is you will all want to go with numbers and say this one has a higher score, so it clearly wins” (i.e., acknowledging the normative supremacy of math and science in engineering). However, Heather also noted that this was not generally the point of the matrix, and highlighted that scores were meant to be negotiated in discussion with each other, in particular because people whose ideas were not seriously considered might be motivated to check out. [Note: Heather is hovering around, but wading into, subjectivity.]
Epistemic Congruence	An actor (i.e., student, instructor, mentor) expresses compatibility between dominant epistemologies in engineering and their own perspectives.	Number one, engineers should rely on math and science when defending their ideas. I feel like yes because math and science is concrete and can be proven by others. Engineers are the ones designing things that are used by other people, so I feel like what they're designing should be based on concrete ideas..
Support for Process Objectivity	A student expresses support for process objectivity-the notion that science is objective in that, or to the extent that, the processes and methods that characterize it	Number one, engineers should rely on math and science when defending their ideas. I feel like yes because math and science is concrete and can be proven by others. Engineers are the ones designing things that are used by other people, so I feel like what they're designing should be based on concrete ideas

	neither depend on contingent social and ethical values, nor on the individual bias of in engineering.	
Rejection of Process Objectivity	A student rejects process objectivity--the notion that	So, the first block, yeah, I agree that math and science should be a big aspect on communicating ideas, defending ideas, but I don't think that's a valid thing, like that's the only thing that you need to start out with. Maybe you can start out with intuition or common sense, or something like that, and then build off of it, and then add.
Support for Product Objectivity	A student expresses support for product objectivity- the notion that science is objective in its products - theories, laws, experimental results, and observations-in engineering.	Now, the second block, I'm not too agreeing on, I guess. I think that there's not only one right answer to every problem. I think there's a lot of different ways to get to different answers and maybe some things work better than others. But I don't think there's only one right answer.
Rejection of Product Objectivity	A student rejects product objectivity-the notion that science is objective in its products - theories, laws, experimental results, and observations-in engineering.	One of my core beliefs is that things just don't work sometimes. So you're not going to always find the best solution. Knowledge and engineering can always be proven true or false, I don't believe that for a second. I believe in having a lot of gray area, So I think that was part of my responses.
Support for Depoliticization	Student expresses support for depoliticization in engineering.	To me, political beliefs or cultural beliefs or social justice concerns are personal beliefs. Some people are more vocal about those things, but I feel like, regardless, no matter what, you bring up any one of those things and you're going to lose half the room. You're going to have half the people not like you. You're going to have someone disagree with you. Whereas, if you just touch on human emotion, everyone can agree with that.
Rejection of Depoliticization	Student rejects the idea of depoliticization in engineering.	They're saying that engineers should leave their personal beliefs out of work and that social justice concerns don't influence work. I think that everybody's work, engineering or not is influenced by their personal beliefs and I don't think engineering is an exception to that, because everybody has their own values and beliefs and that's what they bring to the table. So I don't think they should leave their beliefs out of it.
Change in Engineering-Related Beliefs	A student discusses changes in their engineering-related beliefs, particularly as a result of their experiences in ENGR 100.	Yeah. So I guess now I'd say based on what I've experienced this term, it's... There's more of a human factor that's involved. You can't just rely on numbers and observation just to support your claims. You can't just seem like a robot whenever you try to do something, especially when you're interacting with others. And I guess I put less emphasis on the technical aspect of engineering and trying to

		emphasize more about how to communicate with others, how to present of your ideas, how to come off as more human because that's what engineers are, I guess.
Real Engineering Work	A student discusses what they believe they learned about real engineering work based on their experiences in ENGR 100.	So for like a more formal presentation or something that you'd actually be presenting to like a boss in a job, you'd have to really explicitly say, "Here are what each one of these things are meant to be," as opposed to leaving quite a bit up to the imagination of each individual team member, which is what happened, and I feel like that probably happened for many groups.
Nature and Use of Questioning		
Attacking Question	A student asks an attacking question. Attacking questions are those negatively framed questions that signal opposition to a particular idea.	Kyle was perturbed by this approach, asking, "John, what is this?" Kyle asked what John intended to do with the list, asking, "Are you going to type that into a paragraph or leave it like that?" [Note: I saw this as somewhat a attacking question. The implication was, "I want you to type this into a paragraph."] John responded, "I can make it a paragraph if that makes sense." Kyle: I think that makes more sense as a paragraph. [Note: Read: Make this a paragraph.]
Elaborate Question	A student asks for a student to elaborate on an idea. The "elaborate" question tends to signal the questioner is at least considering taking up the idea.	Kyle went to the board to sketch their ROV. At one point, Paul begins to ask about dimensions to ensure the idea works (e.g., "How tall is the payload? So then we need at least X inches."). From there, Kyle begins to consistently write in dimensions, and over time, we have a fully drawn ROV dimensions.
Hedging Question	A student asks a hedging question during the team meeting. Leading questions are defined as those questions that redirect conversations or ideas and are often ways of signaling the asker's desires or concerns in conversations.	I think there were some concerns. I think we might've talked about on the group chat. If I can just go back and see if there's anything about it. Yeah, Paul brought up, "Is there any way to put the floats sideways in the top of the ROV?" Yeah, this was like a few days after we met and when I made the CAD model. And I said, "I'm sure we could, it shouldn't be an issue." So yeah, there was some pushback about the actual design of the model. Yeah, I think I've... Yeah.
Questioning for Approval	A student asks a question for approval (e.g., to proceed with an idea, action, or task).	Seth often navigated the decision-making process by deferring to other teammates, constantly seeking approval from at least one teammate before making even trivial decisions. For example, as he worked on the text in the slides, he would ask, "Should I put this in this slide?" [Note: On reflection, I wonder if this was more of an "I am going to put this here. Do you approve?"]
Misc. Codes		
External Obligations	Students discuss outside obligations that affect their work on the project.	It was Seth who suggested the team consider a regular meeting, and John who pushed for a weekly standing meeting for the team. After some discussion, including John saying he cannot do Mondays because he watches The Bachelor with his friends, the team initially agreed to meet at 3PM.

Affect of COVID-19	Student discusses the effect of the COVID-19 cancellations on their experiences during the term.	When we're in person, I felt motivated to do everything and I was on top of things, and wanted to... I like seeing something come together, I guess. How about that? But then, kind of once everything hit the fan, it was just weird. I don't know. It's kind of like a drop in everything.
Logistics	A student discusses the role of logistics in their team's design process (e.g., easy/difficulty scheduling meeting, coordinating tasks).	I thought one of the major strengths our team had was in its communication, especially earlier on when it was easy to meet and everything, everybody did a good job with their efforts to come to meetings and do their part in projects and everything.
Skills Gained	A student discusses the skills (e.g., technical skill such as CADing or non-technical skills such as communication) they gained in the course.	I'd say it was generally positive. I think you can agree that things got better for me as the course went on just because of things that happened. I definitely learned a lot about the non-technical aspects of being an engineer. Just Communication, working with others, people skills, stuff like that. Yeah, I think that's really why I got the biggest thing I learned about in this class.
Researcher Positionality	An event of conversation calls into question my position in the course OR I note an interpretation that is tied to my own positionality.	As Heather and I move between teams to discuss ideas with students, I am careful not to give explicit decisions to students. I avoid “this is good” or “this is bad” feedback as well, but I offer reminders consistent with the course's restraints (e.g., “how are you going to attach the payload?” to all of the teams. Heather does this as well.
Lack of Skills	A student discusses their lack of design, building, or communication skills, and the role this played in their team working dynamics.	I would say that in terms of explaining my idea to the rest of the team, it's difficult when... Me, I don't have a lot of drawing experience, so when you have something in your head that you don't even fully understand because you don't have a ton of the skills yet, and then you try to draw it, write that down or draw a sketch to explain it to other people, it doesn't always completely convey exactly what's up here just by fault of you don't have the skills to draw or explain.
Decision due to Difficulty	A student describes difficulty/easiness as a key factor in a design decision their team made.	I remember that there were four or five joints I think on the corners of the square of the runners, I guess if you think about it that way. And then the back tip, there were parts that were just not real parts, I guess, so we would have either had to find them from somewhere, which I don't think we could have done or print them, which would have been, I guess plausible but hard to do and more trouble than it might've been worth.
Barrier to Participation	A student discusses a barrier (e.g., physical barrier such as remote teamwork or social barrier such as feeling uncomfortable) to participation on the team.	I think that's just mostly something on my end because I think all the other four guys, they'd all been pretty familiar with each other. They'd been on good terms for a while. They all knew each other much better than I knew any of them. So, then I think I just didn't really try that hard to try and be a part of an active member of the team. Try to contribute to the design process or try to express my own ideas.
Task Delegation	A student discusses the ways in which tasks were delegated on their team. **NOTE:** Specifics about task delegation (i.e.,	So, really tasks were delegated. Like once we start the design, I was pretty much responsible for the CAD model. John took over the custom parts, so he was responsible for printing, designing it, all that other stuff. Kyle and Seth and Paul, they all took other parts. I think Seth took up more of the financial aspects, like

	person X did A and B tasks) should be coded under "Action Opportunities". This code is meant for a broader discussion about the team's approach to delegation. Sometimes these two things were discussed at once.	parts costs, parts used, material used, stuff like that. And I think Paul, he had more of the calculations like calculating the coefficient drag center points and stuff like that. That's just pretty much carried over through our DDR design reports. Pretty much everything else that we had to do from there. Everyone just assumed the same kind of tasks throughout.
Task Delegation Equity	A student discusses their perceptions about whether task delegation was equitable in their team. This might be (a) taking on tasks that they did not believe should have been their responsibility, (b) being denied the tasks they wanted to contribute to, or other working processes.	I feel like I've spent a lot of time on these presentations, and I know that Lauren has spent just as much time as I have, if not more with the equations. Especially with that... Whatever the second presentation was the one that we had to give in front of the class while we were still there. I think that was my most irritated point because I remember Lauren and I... I worked on that presentation for like 10 hours to this Saturday before it was due or something dumb like that.
Behind-The-Scenes Communication	A student discusses "behind-the-scenes" personal conversations they had with teammates or instructors, and how these personal conversations shaped the design process.	I would say I think that Lauren might've felt uncomfortable sharing some ideas because I think especially during the beginning Danish was maybe championing his idea a little bit more and was less... He was willing to make compromises, but he was much less open to it. And so I actually had a conversation with her and she was like, "This is difficult for me to convince him on my own because he likes his idea."
Agreement with Member Check	A student expresses agreement with my preliminary description of their team or individual profile.	I think yeah, that pretty sums it up, like this pretty accurate. Yeah, I think later on we used fusion because during, instead of SolidWorks because of our inability to access SolidWorks there after they canceled classes. I installed fusion, I think Kevin already had SolidWorks on his laptop, but I felt the need that fusion was better for some reason. I don't know if that's like, it's so pivotal, but yeah, I think that's the only thing.
Disagreement with Member Check	A student expresses disagreement with my preliminary description of their team or individual profile.	Definitely, I felt like gender definitely played a role. I don't think the color... I don't know. I would be interested to hear from your perspective on that, honestly. I would totally respect your opinion on that because, from me, I've always been like, "It's not a big deal."
Team Rules	The team establishes (explicitly or implicitly) rules for social engagement. **Note:** There was an explicit assignment during which teams settled on "team agreements" in the course.	The team settled on the following as general team rules in their agreement during the Team Agreement discussion (copied from their Google Doc): Weekly check-up meetings Sundays at 4pm at the UGLI. Whole team will try to attend, but will fill in information for members who cannot make it in the group chat. We will hold meetings if necessary, for specific details/ideas, will notify the team in GroupMe.
Performance Output		

Design Performance Output	A student completes a contribution to the team's collective design tasks.	Cam updated the team that the CAD model is now completed.
Build Performance Output	A student completes a contribution to the team's collective build tasks.	The meeting began with John showing the team the 3D-printed custom part.
Communicate Performance Output	A student completes a contribution to the team's collective communications tasks.	Following the meeting (see GroupMe), John agreed to update the team logos for the slides. In doing this, he informs the team head to make minor changes to the slide—"shifted some things" on Cam's slide and moving the right side of slide six in Kyle's slide.
Performance Output Ignored	A student's performance output is either ignored, or more broadly not taken up, by the team.	At multiple points in the conversation, John suggests the team will not need sway thrusters. This point, at first, is not acknowledged at all.
Performance Output Acknowledged	A student's performance output is acknowledged, or more broadly taken up, by the team.	At multiple points in the conversation, John suggests the team will not need sway thrusters. This point, at first, is not acknowledged at all. Later, it is discussed, but the team does not make any decisions about the argument (i.e., the point is left without conclusion). Finally, John approached the board and drew out his concept to include an argument against sway thrusters. Finally, the team (particularly Kyle and Paul) takes up the idea, and the team, at least preliminarily, decides they will not need sway thrusters.
Researcher Positionality	An event of conversation calls into question my position in the course OR I note an interpretation that is tied to my own positionality.	Later, I sense that my questions are perceived as "shooting down ideas", so I tell the class, and particularly [peer mentor's] team, that I will problematize all of their ideas, no matter how great the idea seems. [Note: My goal here is to get students thinking about openly providing a rationale for everything they put forward, but I have concerned this push for rationales may doubly harm students of color and women. Perhaps, though, it may even the playing field. If it is true that students of color and women are often forced to defend ideas when their White, male counterparts do not, then it might be true that my questions are "leveling the playing field.]
Affective Responses		
Positive Experience	Student discusses a positive experience on the team/during the term.	I think generally positive. I think you can agree that things got better for me as the course went on.
Negative Experience	Student discusses a negative experience on the team/during the term.	I think we definitely recognized they there were getting torn apart in their presentations.
Role of Instructor		
Description of Assignment	An instructor discusses one of the course assignments. **(Note: This code is particularly**	In the third session (i.e., Wednesday PM), Heather again discussed the purpose of the IDP. Notably, she asked the class why they thought they were assigned the IDP. Student 1 (male): So that everyone has some ideas when we all meet.

	concerned with signals instructors offer about the nature and use of students' work in engineering)	Student 2 (male): Because I want people to choose my design to build. Heather called Student 2's response a "sales pitch" and somewhat undermined the idea. She generally agreed with [student], that the purpose was to bring multiple ideas and perspectives to the table. A third student (male) added, "It's better to listen to everyone's ideas."
Discussion of Engineering Work	An instructor discusses or alludes to "real world" engineering work, or the norms, practices, expectations, etc. of engineering contexts.	Heather then engages the class in a question: Heather: Which of these is most important in an engineering context? After a moment, [student] answers, "ethos and logos, because we need to make sure that we are presenting well and that what we are presenting makes sense." Heather affirms this notion.
Discussion of Eurocentric Epistemologies	An instructor discusses or alludes to the Eurocentric Epistemologies (e.g., the normative supremacy of mathematics and science, objectivity, neutrality).	Today the class discussed weighted decision matrices. Heather began with, "You are all engineers, and my sense is you will all want to go with numbers and say this one has a higher score, so it clearly wins" (i.e., acknowledging the normative supremacy of math and science in engineering). However, Heather also noted that this was not generally the point of the matrix, and highlighted that scores were meant to be negotiated in discussion with each other, in particular because people whose ideas were not seriously considered might be motivated to check out.
Instructor Facilitating Teamwork	A student discusses the role of instructors in facilitating teamwork (e.g., team dynamics, assignments, conflict).	I guess I'll just say you and [Instructor] and Heather, you guys were all just such a big help. Like especially at the beginning when I didn't know if I could do this. So I just got to give a lot credit to you and to [Instructor] and Heather for helping me get through the first few weeks of the term. So, kudos to you guys. You guys were a big help.
Case Study Evaluation		
Design Evaluation	A team discusses design issues in the case study assignment.	Stephanie immediately entered, "They were really maneuverable, they talk about this in the Conclusion… way too maneuverable… not stable enough but way too maneuverable, which honestly is what I think would have happened to ours." (i.e., Stephanie was prepared to have the conversation).
Communications Evaluation	A team discusses technical communications issues in the case study assignment.	"All right. Case Study." The team had a short discussion about their preparation for the meeting. Danish admitted he did not have time to read the material ahead of the meeting. "I'm unprepared." Lauren admitted that she'd only skimmed the document after watching the video, but Stephanie said that this was also her approach. "It was bad (the document) and poorly written!" [joking]
Case Study Design Priorities	A team discusses their understanding of the Case Study design priorities.	Stephanie suggested Ryan record notes for the meeting and share his screen, to which Ryan agreed. Ryan opened the conversation about "OSUs" design by discussing his perceptions of OSU's design goals. Ryan: They wanted it to be small. Stephanie: Compact. They said compact like every other sentence. [laughing]

Video as Evidence	The team describes a design issue using the case study video as evidence	Still, Ryan moved on to the discussion of OSUs “failures.” “Surging created a jolt every time they turned their thrusters on, if you watched the video…”
Report as Evidence	A team describes a design issue using the case study report as evidence.	Ryan, again citing the video and text, noted that the OSU ROV had buoyancy problems. “They weren’t able to heave downward, which was why they were at the surface the entire time.”
Design Revisions	A team discusses the ways in which they would modify the Case Study design to achieve particular design priorities.	Ryan again moved on to the “Performance Observations” section without input from the team. Lauren returned to the discussion of the buoyancy issue, and Ryan directed the team to OSUs CAD model. He noted that the heave thruster was at the top and sticking out of the water and suggested this was the reason they are not able to heave downward. Interestingly, Ryan noted that this was similar to an idea they considered, but “we fixed it because it wouldn’t work.” Ryan again moved on to the “Fixes” section without input from the team. He began typing notes into the section, including that the heave thruster would need to be moved.

Appendix H: Descriptive Profiles for Non-Focal Teams

Table 15. Standardized Mean Scores to ERB Items for Non-Focal Teams

Pseudonyms	Race/Ethnicity	Sex	International Status	Process Objectivity	Product Objectivity A	Product Objectivity B	Depoliticization
Team A							
Eric	Asian	Male	Domestic	0.75	0.70	0.01	-0.93
Grant	White	Male	Domestic	-0.85	0.06	-0.33	-0.64
Greg	White	Male	Domestic	-0.08	-0.49	0.03	-0.49
Jason	White	Male	Domestic	0.39	-0.82	-0.34	1.55
Tony	White	Male	Domestic	0.51	0.76	-0.35	0.97
Team B							
Amy	Asian	Female	Domestic	0.15	0.38	0.03	-0.19
Anna	Asian	Female	Domestic	0.39	0.11	1.45	0.08
Arun	Asian	Male	Domestic	0.47	-0.20	-1.04	-0.34
Dwight	Asian	Male	Domestic	-2.29	-1.40	-0.33	0.97
Elliott	White	Male	Domestic	-1.13	-0.21	0.76	-0.36
Team C							
Joel	White	Male	Domestic	-0.12	-0.59	0.03	-0.50
Omar	Black	Male	Domestic	-0.08	0.06	0.03	0.23
Ron	White	Male	Domestic	0.35	1.32	0.39	-0.48
Salman	White	Male	Domestic	-0.70	0.44	-0.70	-0.93
Vince	Multi-Ethnic	Male	Domestic	-0.58	0.44	0.39	0.65
Team D							
Grace	Asian/White	Female	Domestic	-0.54	-0.75	-0.68	-0.65
Micah	White	Male	Domestic	-0.90	-0.81	-0.32	-0.8
Nate	White	Male	Domestic	-0.3	-0.59	0.35	0.37
Priya	Asian/White	Female	Domestic	0.15	-0.49	-0.35	0.08

Steven	Asian	Male	Domestic	0.01	0.38	0.39	0.23
Team E							
Jared	White	Male	Domestic	1.21	-0.83	-0.33	0.51
Mark	White	Male	Domestic	-0.08	0.99	-0.34	-0.11
Peter	Asian	Male	Domestic	0.08	0.11	0.74	-0.64
Philip	Asian	Male	Domestic	0.94	1.64	-1.04	0.22
Team F							
Alexis	White	Female	Domestic	-1.09	0.17	0.39	1.11
Austin	White	Male	Domestic	0.15	-0.44	-0.68	0.54
Divya	Asian	Female	Domestic	-0.67	0.17	-0.68	0.53
Mehak	White	Female	Domestic	-0.39	1.32	-0.70	-0.92
Will	White	Male	Domestic	-1.56	-0.47	-0.68	-0.93
Team G							
Arya	Asian	Female	Domestic	-0.58	0.39	0.03	-0.64
Cara	White	Female	Domestic	0.47	-0.82	-0.33	-0.33
Darren	White	Male	Domestic	0.63	-0.16	-1.04	0.05
Gavin	White	Male	Domestic	0.50	1.04	-0.35	-0.07
Kayla	Latino/a/White	Female	Domestic	-0.08	-0.20	0.01	0.06
Team H							
Brandon	White	Male	Domestic	-0.22	-0.44	-0.70	-0.22
Elijah	White	Male	Domestic	0.15	-0.59	-1.04	0.22
Reid	White	Male	Domestic	-0.85	-0.16	0.03	-0.34
Robert	White	Male	Domestic	0.16	0.38	0.37	0.51
Scott	White	Male	Domestic	1.44	0.43	1.010	0.23
Team I							
Aaron	Asian	Male	Domestic	0.20	-0.21	0.03	0.23
Asher	White	Male	Domestic	0.19	0.12	0.01	0.50
Ben	Asian	Male	Domestic	0.39	0.70	1.82	0.51
Bruce	White	Male	Domestic	0.39	-0.50	-0.34	-1.37
Dmitry	White	Male	International	0.15	-1.41	-0.33	-0.35

Appendix I: Contribution and Enactment Networks for Focal and Non-Focal Teams

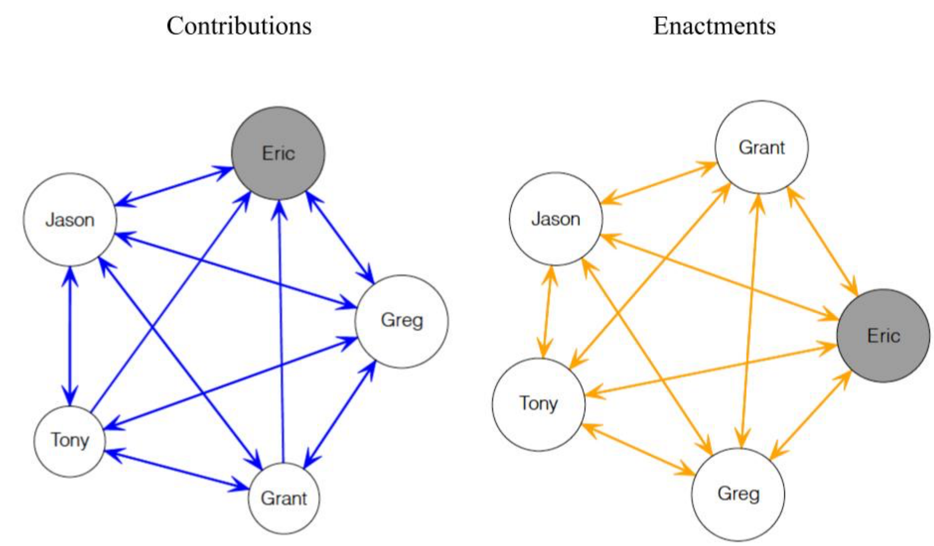


Figure 13. Team A Contribution and Enactment Networks

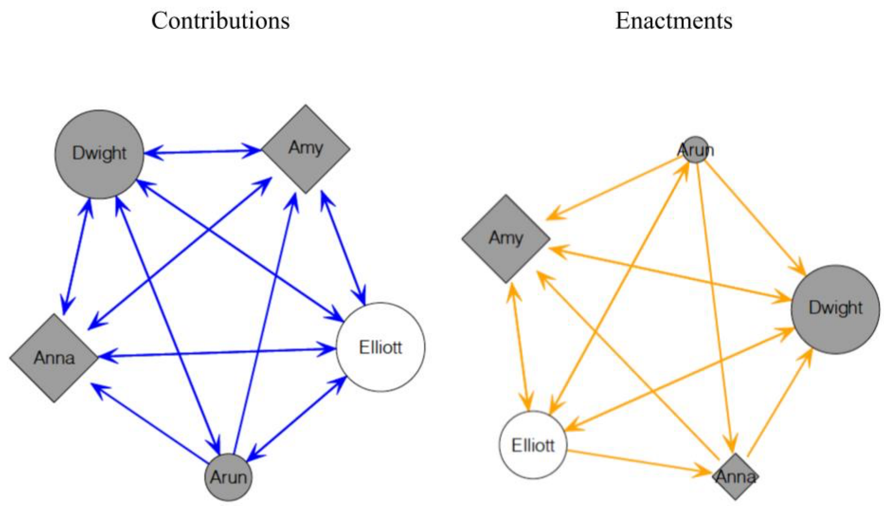


Figure 14. Team B Contribution and Enactment Networks

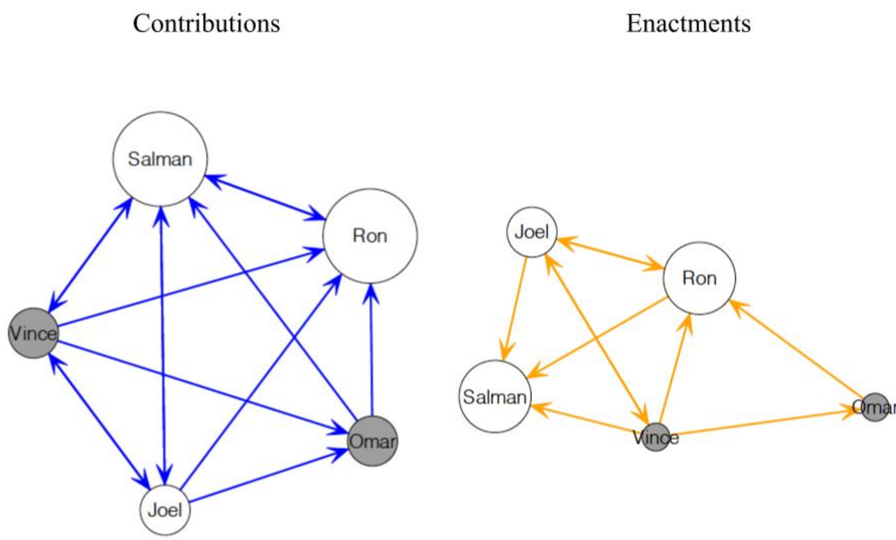


Figure 15. Team C Contribution and Enactment Networks

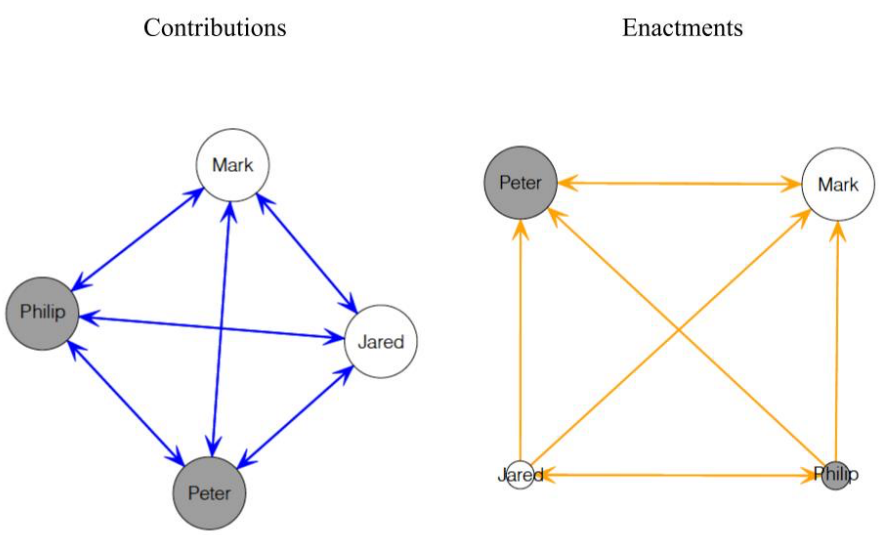


Figure 16. Team D Contribution and Enactment Networks

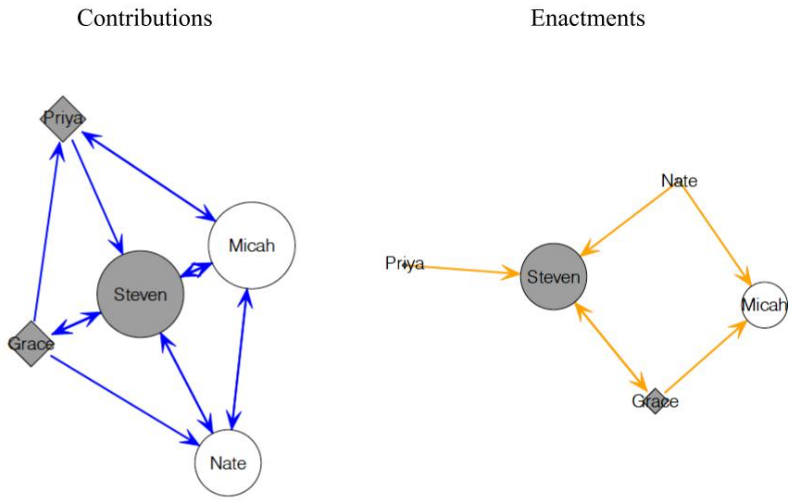


Figure 17. Team E Contribution and Enactment Networks

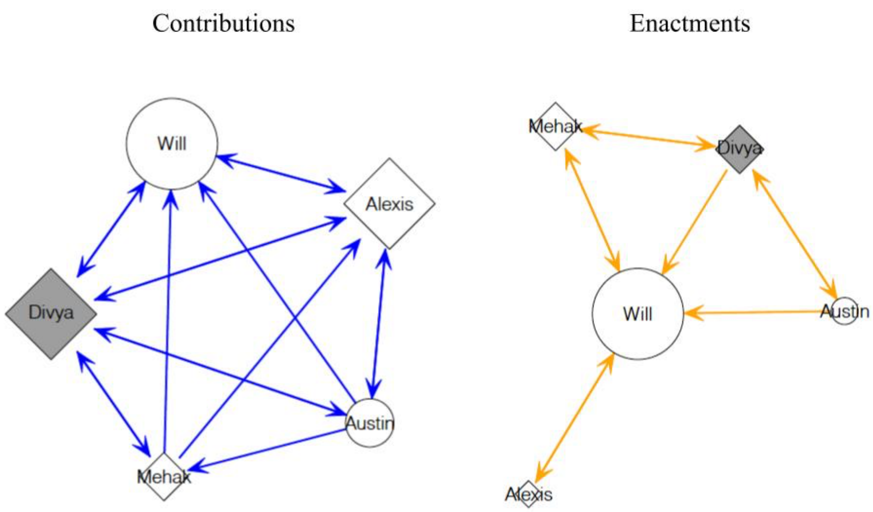


Figure 18. Team F Contribution and Enactment Networks

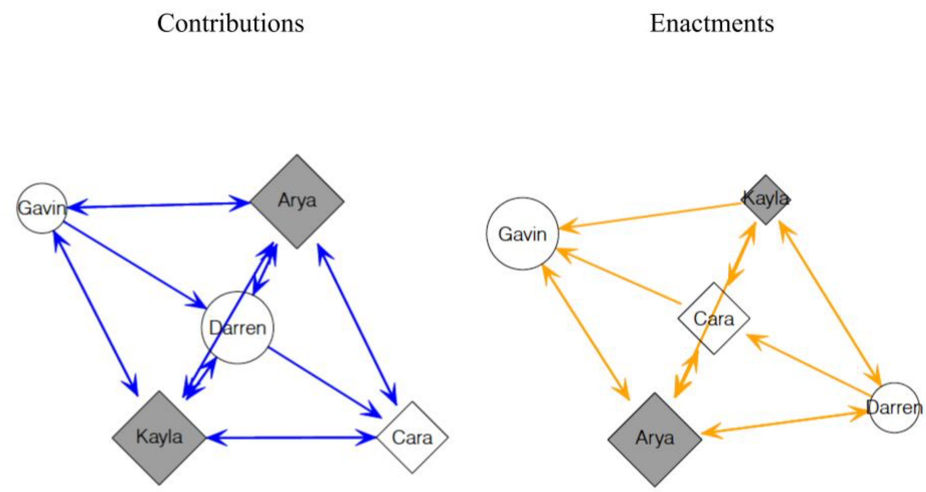


Figure 19. Team G Contribution and Enactment Networks

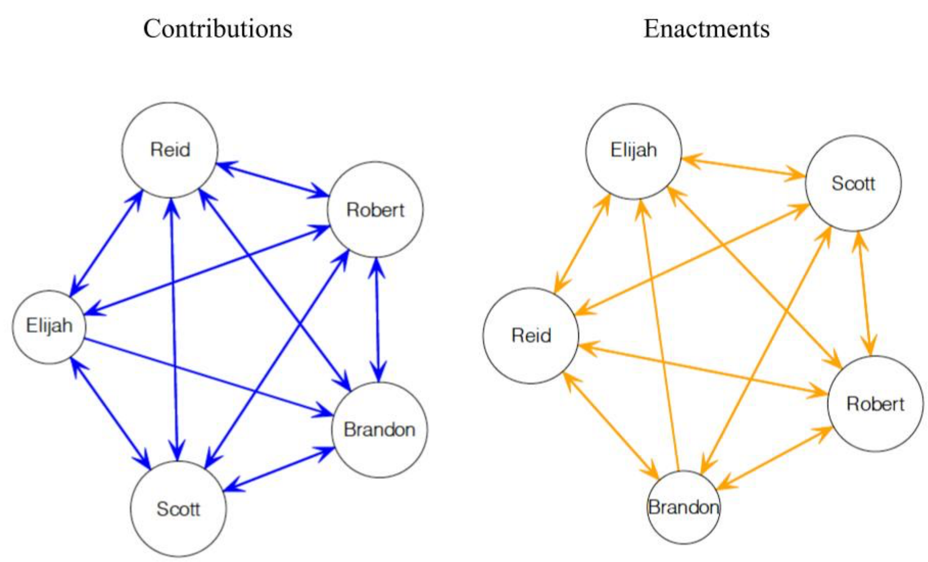


Figure 20. Team H Contribution and Enactment Networks

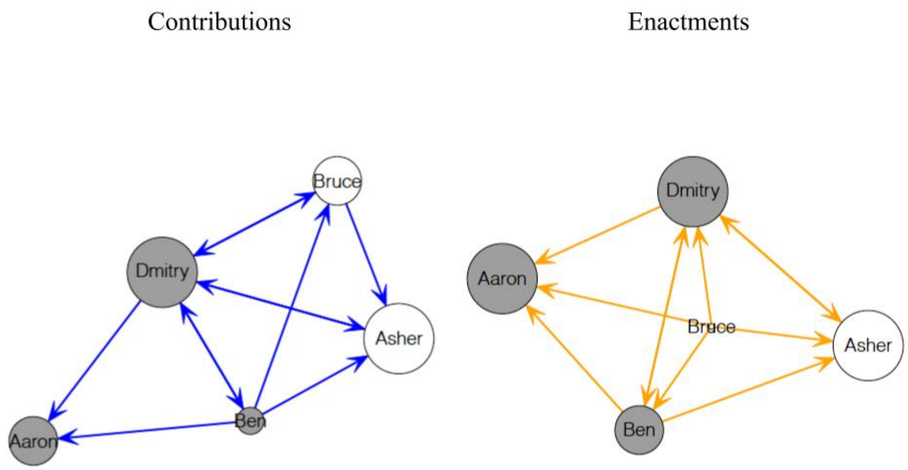


Figure 21. Team I Contribution and Enactment Networks

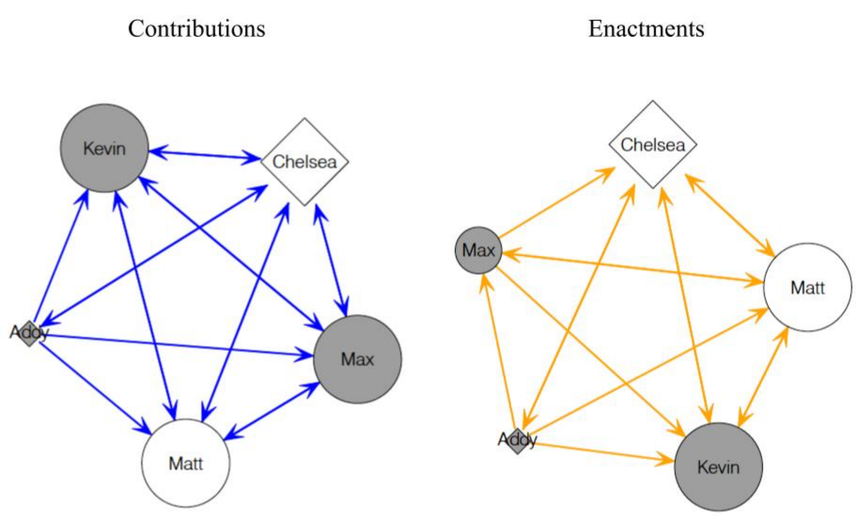


Figure 22. Team Mobula Contribution and Enactment Networks

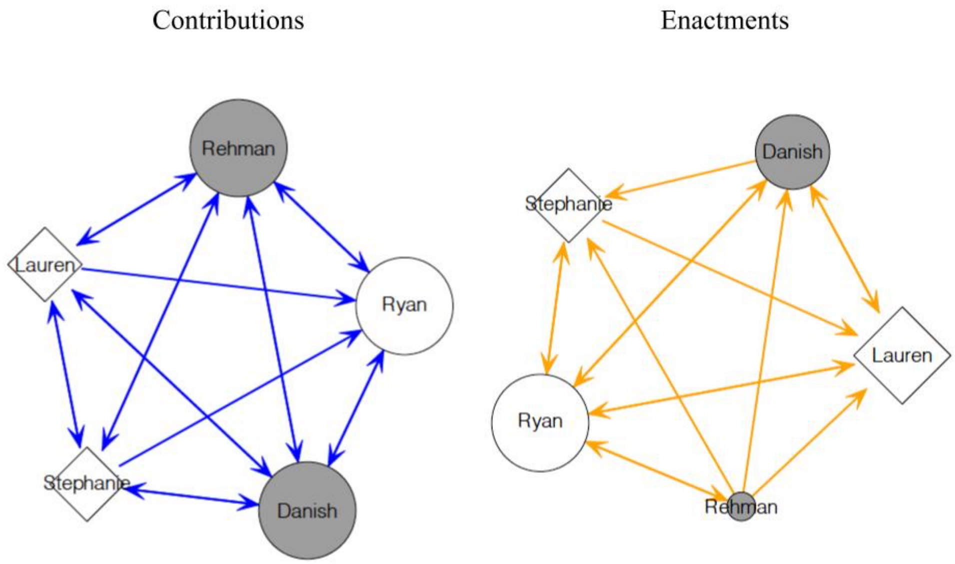


Figure 23. Team Surge Contribution and Enactment Networks

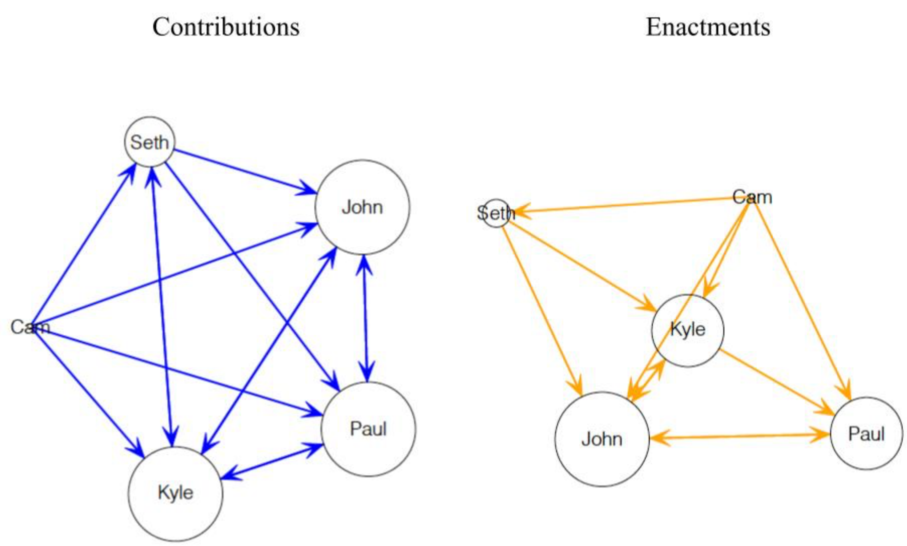


Figure 24. The Yachtsmen Contribution and Enactment Networks

Appendix J. Goodness-of-Fit and Degeneracy Diagnostics

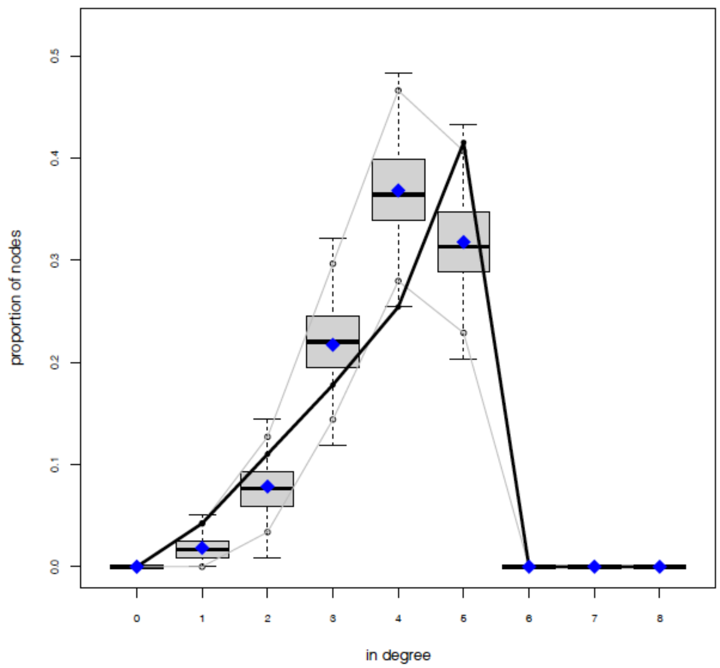
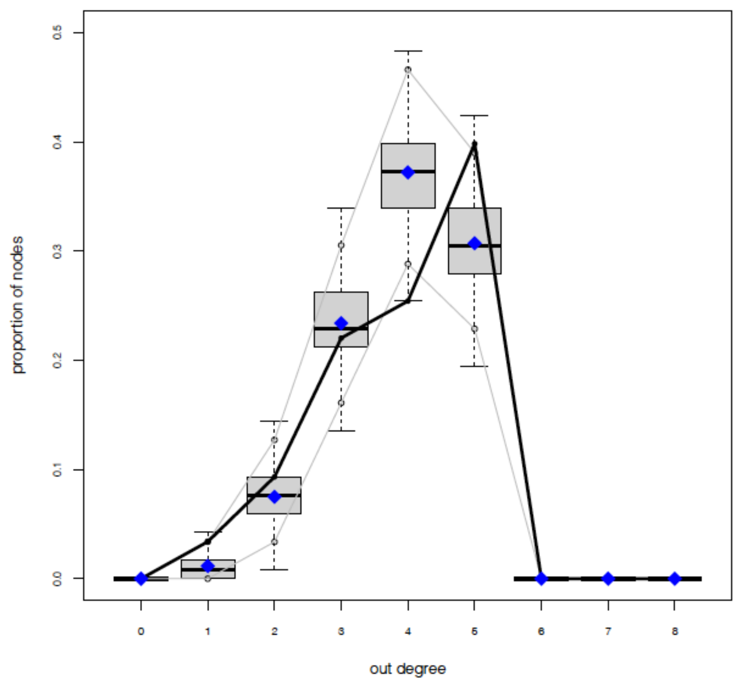


Figure 25. Goodness-of-Fit Plots



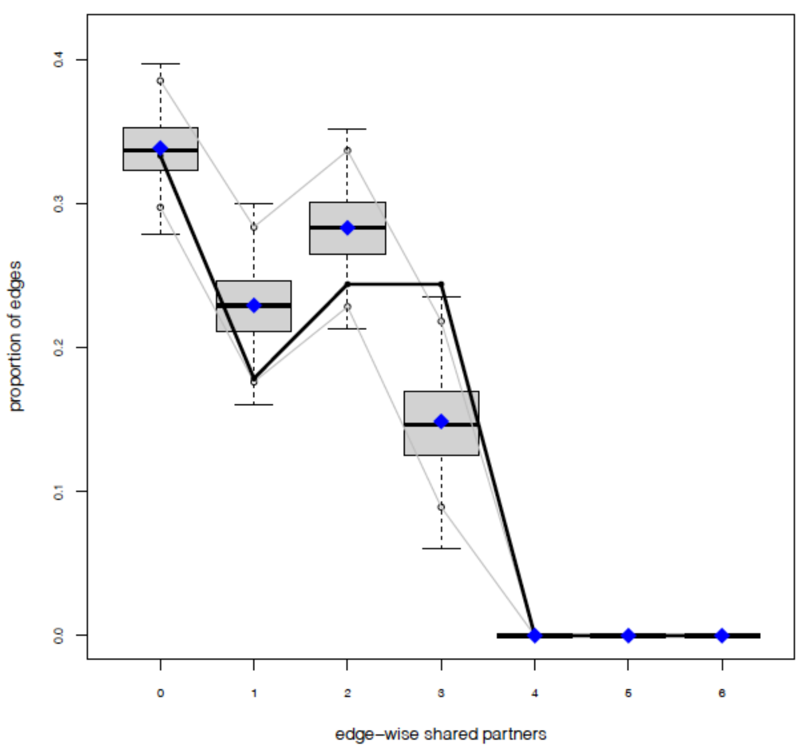


Figure 25 (cont.). Goodness-of-Fit Plots

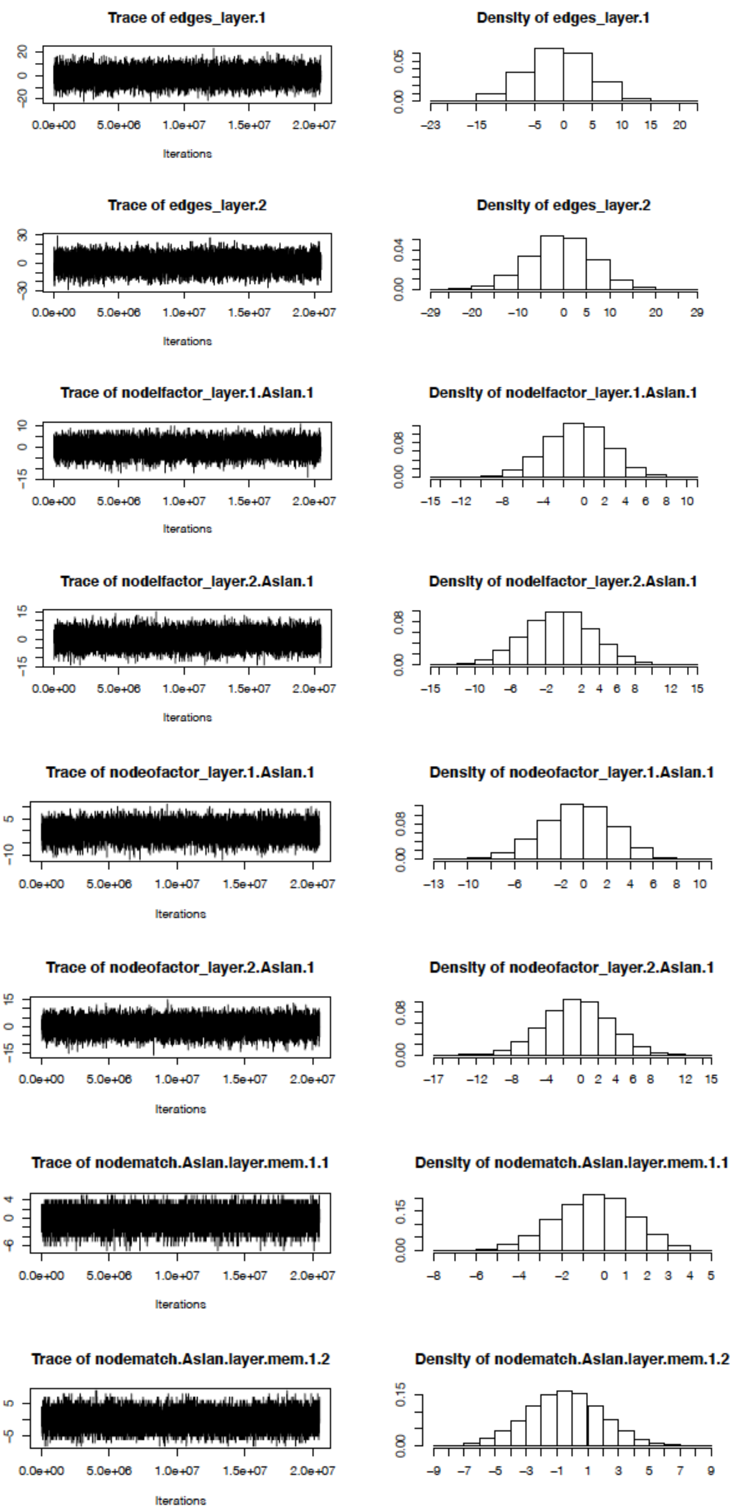


Figure 26. MCMC Diagnostics

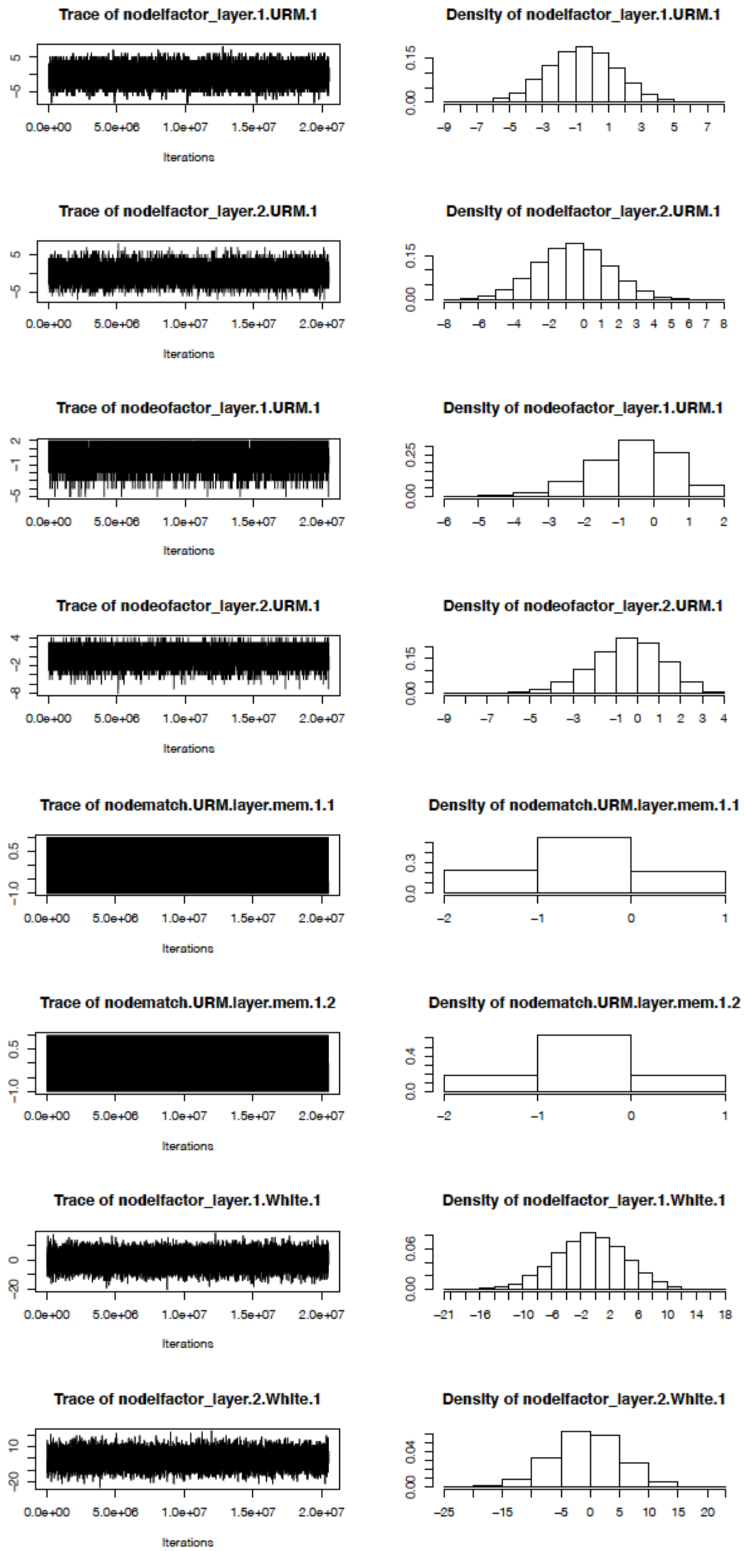


Figure 26 (cont.). MCMC Diagnostics

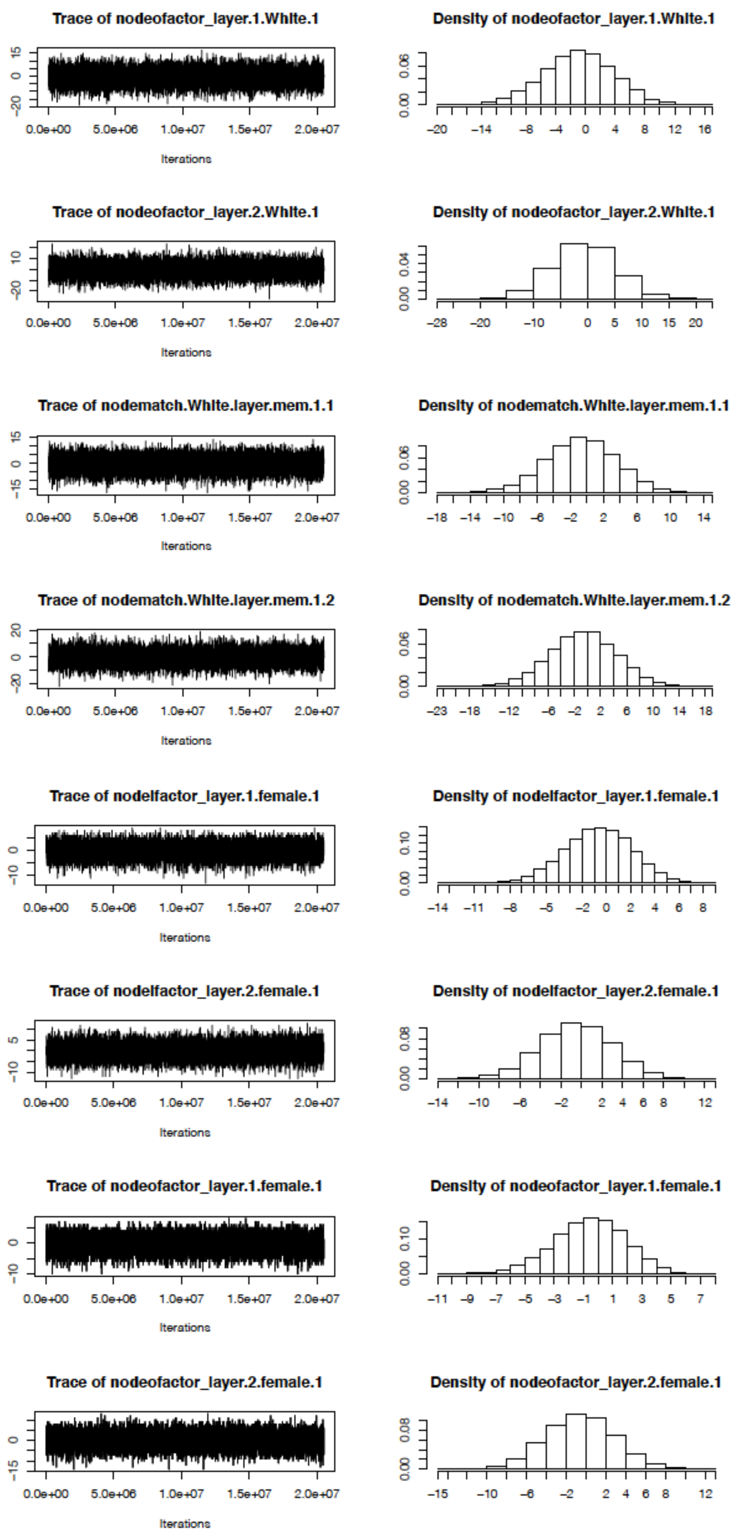


Figure 26 (cont.). MCMC Diagnostics

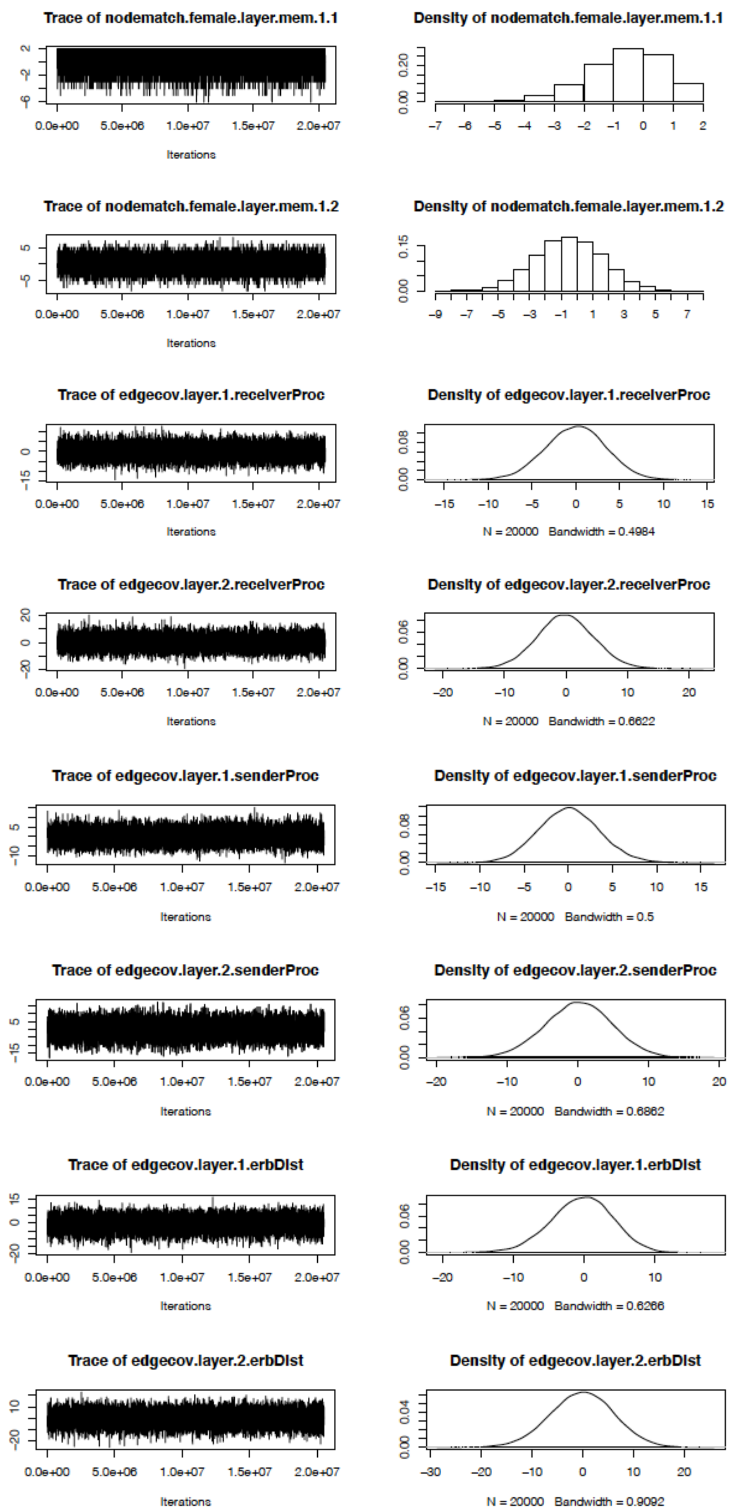


Figure 26 (cont.). MCMC Diagnostics

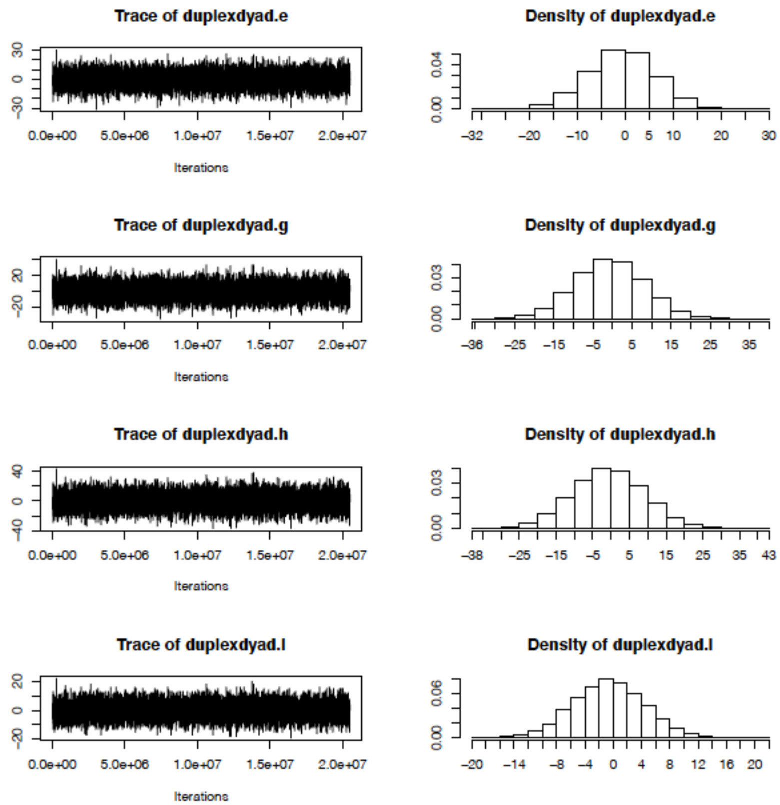


Figure 26 (cont.). MCMC Diagnostics