(RE)CONSTRUCTING THE PROFESSIONAL FORMATION OF ENGINEERS: A HUMAN-CENTERED MODEL OF COMMUNICATION DESIGN

by

David H. Torres

A Dissertation

Submitted to the Faculty of Purdue University

In Partial Fulfillment of the Requirements for the degree of

Doctor of Philosophy

Brian Lamb School of Communication

West Lafayette, Indiana

May 2019

THE PURDUE UNIVERSITY GRADUATE SCHOOL
STATEMENT OF COMMITTEE APPROVAL

Dr. Patrice M. Buzzanell, Chair
Brian Lamb School of Communication
Dr. Stacey L. Connaughton
Brian Lamb School of Communication
Dr. Seungyoon Lee
Brian Lamb School of Communication
Dr. Carla B. Zoltowski
School of Engineering Education
Dr. Andrew O. Brightman
Weldon School of Biomedical Engineering

Approved by:
Dr. William B. Collins
Head of the Graduate Program

For my loving family—Mom, Luquin, Becky, Lily, and William.

ACKNOWLEDGMENTS

Acknowledging all those who have supported me throughout this project would be a dissertation effort in and by itself. Patrice M. Buzzanell who provided challenging intellectual guidance while maintaining the grace and understanding of a friend. Stacey L. Connaughton for truly being a second advisor to me on this project and throughout my graduate work at Purdue. Seungyoon Lee for being a teacher and advisor from the first day I visited the program. Andrew O. Brightman for challenging me to think differently and pushing me to be an expert of my research. And to Carla B. Zoltowski. I learned so much from you working day-to-day, late nights, and early mornings! I am so grateful to call you a mentor, advisor, colleague, and friend. Thank you.

A very special thanks to those I am grateful to call my friends. To Kyle, Katelin, Doris, Brad, Drew, Andy, and David. Your unwavering friendship and support provided me with the encouragement and levity to see this through. And another thanks to a special group of amazing women who have carried me, encouraged me, and made me laugh during the most challenging parts of this work. Thank you Jocelyn, Sarah, Valentina, Sasha, Yesenia, and Sophie. You have all been a surprising blessing.

Last, and importantly, thank you to my family. A paragraph in an acknowledgements section will not do justice how you carried me. Mom for your unconditional support and love. Luquin and Becky for your guidance and perspective. And Lily and William for always being the best part of my day. You all are my rock and I love you so very much.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Author: Torres, David, H. Doctor of Philosophy
Institution: Purdue University
Degree Received: May 2019
Title: (Re)constructing the professional formation of engineers: A human-centered model of communication design.
Committee Chair: Dr. Patrice M. Buzzanell

This study introduced a design-inspired approach to unpack problems of professional formation of engineers: 1) the gap between what students learn in universities and what they practice upon graduation; 2) the perception that engineering is solely technical, math, and theory oriented; and 3) the lack of diversity and inclusion (incorporation of difference in perspectives, values, and ways of thinking and being engineers) in many engineering programs. The current project investigated the discursive practices and institutional processes that contributed to or inhibited innovative and inclusive professional formation within an undergraduate engineering setting. Specifically, this project showed how Grounded Practical Theory (GPT), Communication as Design (CaD), and Human-Centered Design (HCD) offer alternative pathways to conceptualize the processes of professional formation.

The context for this study involved the professional formation of engineers at a School of Biomedical Engineering (BME) at a large, Midwestern university. Participants for this study included undergraduate students and faculty, staff, and administration (FSA). Semi-structured interview data was collected and explored participants' descriptions, accounts, and experiences related to professional engineering formation in BME. Data collection included 33 total interviews including 15 FSA and 18 student interviews. The study involved an empirical examination of discursive practices that invoked, reproduced, and maintained discourses of professional engineering at the BME school.

Based on insights gained from the empirical examination of discursive practices, a GPT framework was applied to examine conflicts in professional formation, strategies participants used to overcome these challenges, and the underlying rationale for these strategies. Specifically,

the goal of gaining a broad knowledge base—incorporating expertise across various engineering and science disciplines—often can come at the expense of realizing specific application and technical know-how. For many participants, both goals were critical for becoming a professional biomedical engineer but often times blocked a discourse of professional formation that was innovative and inclusive. Participants revealed that a standard lecture curriculum influenced this tension, in many cases for the worse. However, findings suggested that strategies for overcoming these conflicts were by integrating lecture curricula with more active learning formats (e.g., undergraduate research, lab participation). Moreover, findings showed how standard lecture communication designs shaped and maintained a discourse community more likely to emphasize understanding engineering as a science and also gaining a broad knowledge base often times at the expense of realizing specific application and technical know-how.

This study's analysis offers several theoretical contributions. First, GPT pointed to the deeply integrated relationship between the ontological and epistemological foundations of biomedical engineering professional formation. That is, becoming a biomedical engineer meant having knowledge of several sets of disciplinary expertise while also understanding when and how to enact this knowledge in practice. Second, professional formation *designs for communication* (e.g., lecture designs, active learning designs) presupposed something about the recurrent practices held within the school and how these recurrent practices constituted professional ontology and epistemology in ways that were both enabling and problematic, Third, and from a HCD perspective, exploring designs for communication brought to life the ways participants, through interactivity, actively designed discourses of professional formation in an attempt to achieve and meet their epistemological and ontological goals.

CHAPTER 1: INTRODUCTION

The National Science Foundation (NSF, 2015) launched The Professional Formation of Engineers (PFE) initiative "to create and support an innovative and inclusive engineering profession for the 21st Century". The current study addresses issues of professional formation in engineering as part of a larger, multi-year NSF PFE grant (Zoltowski et al., 2017). The grant project was created to address the following three interrelated issues of professional formation: 1) the gap between what students learn in universities and what they practice upon graduation; 2) the perception that engineering is solely technical, math, and theory oriented; and 3) the lack of diversity and inclusion (incorporation of difference in perspectives, values, and ways of thinking and being engineers) in many engineering programs (Eddington et al., 2018, Joshi et al., 2018, Zoltowski et al., 2017).

These issues are interrelated to the extent that epistemological and ontological understandings of what it means to be an engineer and of doing engineering work underscores processes of professional formation, the professionalization of engineers. As such it is important to briefly recognize historical influences of engineering education for what it means to be an engineer and what engineers should know. One of the more significant shifts in engineering education occurred during the early and mid portion of the 20th century (for five major shifts in engineering education, see Froyd, Wankat, & Smith, 2012). Engineering schools in the United States identified a deficit in engineers' ability to address complex problems during WWII, as compared to scientists. As such, many engineering programs began to shift from a practical or "hands-on" curriculum (e.g., machine shop work, surveying) to an engineering science curriculum. Engineering science in this sense included topics in "mechanics of solids, fluid mechanics, thermodynamics, heat and mass transfer, electrical theory, nature and properties of materials" (Berry, DiPlazza, & Sauer, 2003, p. 468). The shift to engineering science situated theoretical knowledge, in many ways, above and beyond practical knowledge.

The knowledge shift in engineering education had important implications for engineering ontologies—in other words, what it meant to be engineer. Centering theoretical knowledge contributed to understandings of engineering as an "engineering scientist" rather than an "engineering practitioner" rooted moreso in practical knowledge (Issapour & Sheppard, 2015). In the current project I discuss how theoretical and practical epistemologies alongside engineering scientist and practitioner ontologies are equally important for becoming a professional engineer. These underlying epistemologies and ontologies have significant implications for how engineers are prepared for the workforce as well as for maintaining an profession inclusive of different ways of thinking and being.

A good deal of research in the area of engineering education has highlighted the gap between what engineers learn and what engineers do in professional practice (Carrico, Winters, Brunhaver, & Matusovich, 2012; Atman et al., 2010; Trevelyan, 2007). These studies suggest engineers are ill-equipped to handle the complexity of their careers with particular emphasis given to the lack of exposure to or knowledge of dealing with integrating the technical with the social dimensions of engineering (i.e., working with, accounting for, and resolving human experiences).

Studies in professional formation of engineers in and by their experiences at the undergraduate level more often than not constitutes engineering as purely a technical profession (Godfrey & Parker, 2010; Radcliffe, 2006). The emphasis across many programs includes the theoretical and technical knowledge of engineering with limited exposure to and experience with the social complexities of the profession (Atman et al., 2010; Trevelyan, 2007, 2010). That is, many engineering programs' curricular formats (e.g., lectures, problem sets, homework assignments) are geared more towards technical and theoretical understandings of engineering than to the non-technical skills that can make engineers successful in their work and careers. The predominance of theoretical understandings and theoretical knowledge is attributed to the engineering science turn in the 20th century. Thus, the discourse of engineering in many cases presents engineering as solely technical rather than socio-technical practice (Trevelyan, 2007, 2010) involving social dimensions such as team and technical coordination, interpersonal communication, and leadership. However, "socio" in this case also goes beyond "working with people" insofar as it relates to understandings and practice of how technical and theoretical elements of engineering interact with real-world factors such as uncertainty, risk, empathy, environment, as well as, with team and technical coordination, interpersonal communication, and leadership.

Reducing engineering to solely a technical and theoretical profession contributes to issues of professional preparation as well as issues of diversity and inclusion. That is, the lack of a "socio" orientation not only produces future engineers ill-equipped to handle the socio-technical complexities of their careers but also constitutes a profession that is unwelcoming and otherwise uninterested in any aspects of professional formation above and beyond technical knowledge (Godfrey, 2015; Tonso, 2007). As such, individuals who are more likely to appeal to more social-centered professions may find it difficult to find a place in engineering. This socio-technical "dilemma" leaves a profession lacking difference in perspectives, values, and ways of thinking and being engineers (inclusion) while at the same time developing engineers ill-equipped to handle the complexities of their career. Academic and popular literature frequently highlight how diversity in fact makes individuals, groups, and organizations smarter and more innovative (see Diaz-Garcia, Gonzalez-Moreno, & Saez-Martinez, 2013; Friedman, Weiser Friedman, & Leverton, 2014; Phillips, K., 2014).

These issues are fluid, complex, and multi-faceted. Attempts at solving one may often times exacerbate many others. What is required is a theoretical, methodological, and pragmatic approach that begins with understanding the underlying epistemological questions of professional engineering (how do engineers know; what engineering knowledge is valued) as well as the ontological premises for what it means to be a professional engineer (what do engineers do; how should engineers interact). Additionally, design-inspired frameworks are needed to unpack desired ends in professional formation and processes by which stakeholders (re)construct their social and material worlds in order to realize their desired goals. These complex questions can point to factors that enable and limit innovative and inclusive professional formation and what areas are amenable to change.

To lay out this dissertation project in this introductory chapter, I begin with the (a) purpose of this study and relationship of the current study to the larger NSF grant. I turn to (b) two perspectives on identity– a communicative and an engineering education perspective. Next I discuss my (c) metatheoretical and disciplinary commitments that are foundational to this study. Given my metatheoretical commitments I then (d) present the theoretical concepts, frameworks, and exigencies addressed in this study. I follow with (e) details of the organizational context for the study and conclude this chapter with a (f) summary and preview of the remaining chapters.

Purpose of Study

The aim of the broader NSF grant was to implement a design thinking approach to develop solution(s) that address three interrelated objectives: (a) to better prepare engineers for today's workforce, (b) to broaden understandings of engineering practice as both social and technical, and (c) to create and sustain more diverse and inclusionary engineering programs. The NSF study involved key stakeholders (students, faculty, staff, and administrators) from schools of electrical and computer engineering (ECE) and biomedical engineering (BME) in the research and design process to co-create solutions that could address the three interrelated objectives.

The NSF study was organized around the three phases of the design process (inspiration, ideation, and implementation; IDEO, 2019) and addressed the study goals in an integrated, participatory, and iterative manner. The specific outcomes of the study included:

1. An understanding of the similarities and differences of the culture, ontologies, and epistemologies of ECE and BME engineering programs
2. An understanding of how (1) impacts the diversity and inclusion of the disciplines
3. An understanding of how (1) and (2) impact professional formation within the disciplines
4. A process of applying design thinking to complex issues in engineering education

The current dissertation project integrated principles from communication and design theory to address the overarching exigencies presented by the NSF with special attention given to the study's objective "to better prepare engineers for today's workforce." The current project investigated the discursive practices and institutional processes that contributed to or inhibited innovative and inclusive professional formation within an undergraduate engineering setting. Specifically, and analogous to Kuhn's (2008) alternative communicative theory of the firm, this project showed how Grounded Practical Theory (GPT), Communication as Design (CaD), and Human-Centered Design (HCD) offer alternative pathways to conceptualize the processes of professional formation. Specifically, this study introduced a design-inspired approach to unpacking problems of professional formation: 1) the gap between what students learn in universities and what they practice upon graduation; 2) the perception that engineering is solely technical, math, and theory oriented; and 3) the lack of diversity and inclusion (incorporation of difference in perspectives, values, and ways of thinking and being engineers) in many engineering programs. These issues are critical to the professional formation of engineers and have yet to be explored from a holistic or integrative approach. In other words, problems in/by professional formation of engineers require approaches that are interconnected and involve core issues of identity, knowledge, culture, and curriculum.

I argue that existing models have produced simplified assumptions and narrow understandings of the various underlying and interconnected concepts of professional formation, not wrong or invalid, rather limited in scope and thus unable to capture the highly integrative and "wickedness"[1] (Rittel & Webber, 1984) of problems related to the professional formation of engineers. This study offers, in the same way as Kuhn (2008), "an early step – a rationale, an agenda for further development, and a set of issues to pursue" (p. 1247). To include and address the range of conceptual elements, dilemmas, goals, and strategies in/by professional formation, there needs to be a view that involves detailed knowledge of the various organizing processes that make up and contribute to ontological and epistemological foundations, or ways of doing and knowing engineering, of professional formation. Offering such an inclusive perspective, this projects appeals to researchers of professional formation across various disciplines.

Given this study's relationship to the PFE initiative and larger NSF study, in addition to my own disciplinary commitments, I speak to and address both organizational communication and engineering education communities. As such, throughout the project I highlight points of contribution to both audiences.

---

[1] As noted by Camilus (2008), "A wicked problem has innumerable causes, is tough to describe, and doesn't have a right answer. …Not only do conventional processes fail to tackle wicked problems, but they may exacerbate situations by generating undesirable consequences."

A central focus for this project is the epistemological-ontological question, *what does it mean to be an engineer*? At the core of this question, is an understanding of identity and unpacking meanings of professional engineering identities to the extent that exposing enabling and inhibiting identity premises can lead to more innovative and inclusive professional formation processes. Given this project's contributions to both organizational communication and engineering education communities, in the following section I address my communicative orientation toward the concept of identity as well as highlight engineering education perspectives that informed the current study.

Identity—a communicative perspective

Following the communicative traditions of scholars such as Alvesson and Kärreman (2000) and Fairhurst and Putnam (2004), a discursive perspective views identities as produced, shaped, and maintained by broader discourses that are culturally and historically situated. Discourse is defined as "organized ways of talking, writing, and acting accordingly…discourses reside in communities of people who collaborate in enacting what constitutes their community…organizes their actions, and construct(s) the worlds they see" (Krippendorf, 2006, p. 11). Similarly, I view discursive practices or discursive identification as instances of calling on, invoking, or otherwise calling to action a particular discourse (Cooren, 2015). For instance, and in terms of the current study, I was interested in the practices that invoked, reproduced, and maintained discourses of professional engineering within a school of biomedical engineering. A discursive approach revealed how professional engineering, as discourse communities, were constructed and maintained by discursive practices.

Discourse communities in this sense involved institutionalization of "recurrent discursive practices, legitimizing methods, and…the emergence of social hierarchies" (Krippendorf, 2006,

p. 9). Professional communities, such as engineering, maintain recurrent discursive practices, specific vocabularies, discourse-specific realities, and legitimized ways of conceptualizing the world (Cooren, 2015; Krippendorf, 2006). Investigating how engineering is discursively constituted revealed interactional and communicative dilemmas–problems that individuals confronted and designed, communicatively, to reach desired outcomes.

From an organizational communication perspective, identities (as discursive products) organize the way individuals make sense of their organizational life and negotiate the various organizational meanings they encounter (Larson & Pepper, 2003). Kuhn and Nelson (2002) defined the process of identifying as a "*discursive process* implicating, shaping, expressing, and transforming identity structures that occurs during coparticipation in coordinated (i.e., organizational) activity" (p. 7, emphasis in original). Related to the present study, a discursive perspective unpacks the way individuals invoke discourses, such as professionalism, engineering practice, and education (among others) and how invoking these discourses constitute professional engineering identities and professional engineering communities. Examining this process can identify those contextual and historical influences that enable and inhibit innovative and inclusive professional formation processes–a central aim of the broader NSF study and a specific contribution of the current project.

The discursive process of identifying also has links to concepts, such as, *belongingness*, *attachment*, and *membership*. Mael and Ashforth (1992) defined identification as the "perception of oneness with or belongingness to an organization" (p. 104). The same premise can be expanded to a perception of belongingness to understandings of professions. Invoking particular discourses in the professional formation of engineers include belonging and membership claims, produced and reproduced in discursive practices, that may serve some and not others–an inclusion problem. Similarly, invoking professional formation discourses include normative claims for how professional formation *should* be enacted, limiting possibilities for integrative and transcendent solutions–an innovation problem. Thus, unpacking the discursive performance of professional formation addresses central concerns for both the current project and larger NSF study. That is, a discursive perspective is uniquely situated to address how engineering educators can create professional formation processes that involve integrative and transcendent thinking, doing, practicing, and valuing of multiple professional engineering identities.

Identity—An engineering education perspective

The question of being or identity is also related to perceptions about the nature of engineering practice. Stevens, Johri, and O’Connor (2014) contend that full understandings of engineering as taught and practiced will not be achieved until there is attention “not just to what people learn and know but also to who they are and what their place is in the world among their consociates as engineers, both within their local professional networks and within social life more broadly” (p. 126). Therefore, the challenges facing engineering education, especially those related to innovation and inclusion, go beyond developing knowledge and skills, but also include perceptions of engineering practice and understandings of engineering identity (i.e., what it means to be an engineer). Understanding salient dimensions of an engineering identity as such is critical for professional formation as well as for recognizing possible boundaries for inclusion and opportunities for innovation.

Unpacking core values and assumptions of engineering identity provide an opportunity for engineering educators to create more innovative and inclusive environments. Students’ experiences of engineering within their undergraduate education shape their understanding of the nature of the work done by engineers, the skills and knowledge that are valued and needed in engineering, and whether these things align with their personal identity and values. These aspects of engineering identity are prime territory for developing an innovative and inclusive environment that acknowledges and invests in diverse perspectives.

Specifically, Trevelyan (2010) speaks to the salient social and technical values found in engineering. He argues “there is a tendency among engineers to define ‘real’ engineering in terms of the technical ‘nuts and bolts’ and scientific and mathematical labor, thereby locating the social aspects of heterogeneous engineering outside of ‘real’ engineering (cf. Trevelyan, 2010)” (Stevens, Johri, & O’Connor, 2014, p. 127). Separating the “technical” and “social” as such limits any possibilities for a heterogeneous view of engineering, where in fact the social and technical are inextricably tied together.

Positioning technical characteristics as “real engineering” inhibits individuals from identifying with the social aspects inherent in engineering. For instance, BME has displayed radical differences from peer departments in terms of undergraduate female participation rates. Studies (See Godfrey, 2015) have found that female students identified more with BME due to the salience of social characteristics such as working and helping “real” people. Thus, embracing both social and technical dimensions of engineering identity is critical for creating diverse and inclusive environments.

In sum, addressing what it means to be an engineer helps engineering educators in two key ways. First, integrating the social and technical shifts notions of diversity and inclusion from a singular problem that needs to be “fixed” into framing diversity and inclusion as practices. Evident in practice, social and technical dimensions are in constant flux and thus should be conceptualized as processes rather than as two distinct and static entities. Second, a more comprehensive view of engineering identity affords more experiences with which diverse individuals can identify (Tonso, 2014) and feel welcome as participants (i.e., "engineering is for me, too."). Similar to the BME example, an engineering identity that values both social and technical dimensions presents more values and premises with which individuals can identify thus leading to more innovative and inclusive academic programs.

Metatheoretical and organizational communication commitments

As an organizational communication researcher, my metatheoretical and communicative commitments provide a unique and valuable layer of insight for both engineering education and communication communities. Social constructionism serves as the meta-theoretical foundation for my dissertation project. Social constructionists believe that meaning and understanding are formed through social systems and broader social discourses (Allen, 2005). Importantly, social constructionism highlights the importance of language in the construction process of our realities (Allen, 2005; Gergen, 1985; Leeds-Hurwitz, 1995). Similar to Brenda Allen's (2005) interests and work on identity, I too am interested in identity formation and specifically in the social constructed knowledge of what it means to be a professional engineer. Unpacking professional engineering identity as such can reveal possible barriers and challenges for the engineering profession in terms of creating innovative and more inclusive professional formation environments. As such, a communicative lens is critical for unpacking how social realities and knowledge in/by professional formation processes are constructed.

In terms of ontological commitments, social constructionism presents the realities of human life as social constructions. These constructions are products of social systems of historically and culturally situated, communicative interactions and larger political and social discourses. In other words, constructions are products of social processes rather than representations of some reality (Gergen, 1985). As such, the epistemological foundation of social constructionism views knowledge as culturally and historically situated. As Gergen (1985) argues, "knowledge is not something people possess somewhere in their heads, but rather, something people do together…shared activities" (p. 270). Language produces the knowledge that we use to make sense of our worlds. Thus, knowledge is intersubjective and constructed by the sociocultural context, social interactions, and broader discourses.

As can be found in many organizational communication research programs, social constructionism offers a framework to explore the social processes and communicative practices of organizing and meaning within organizational life. Social constructionism especially affords organizational communication research in identity formation. Allen (2005) states "an emerging body of work views organizations as primary sites of identity formation where everyday practices help members construct their identities as well as their knowledge about others' identities" (p. 46). Organizational communication studies build on social constructionism assumptions and examine the relationship between larger socio-historical discourses, micro and routine social interactions, and social action. Exploring identity as a range of constructions (Allen, 2005) shows "how specific organizations appropriate, reproduce, and/or transform social discourses in and through everyday communicative processes that enable and/or constrain how members enact identities" (Trethewey, 2000, para. 38).

In terms of the current project, a school of biomedical engineering serves as the primary site of professional engineering identity formation. This particular organizational site carries dominant ideologies and discourses of what it means to be an engineer. These larger socio-historical influences manifest themselves in the daily interactions, and descriptions of these interactions, among organizational members (i.e., students, faculty, staff, and administration of each school) that shape and maintain what it means to be an engineer or "knowledge" of becoming a professional engineer. Understandings of engineering professional formation influences decisions and behaviors and consequently how someone "should" think, behave, or otherwise act in accordance to socially constructed engineering identities. Unraveling the ontological and epistemological foundations of professional formation, throughout this study, revealed which aspects of professional engineering identities enabled and limited transformation and inclusion throughout the professional formation process. Importantly, a social constructionism metatheoretical framework points to how social constructions vary and change which ultimately illuminate areas of professional formation that are amenable to design and change. Given my metatheoretical commitments I next present grounded practical theory (GPT) (Craig & Tracy, 1995), Communication as Design (CaD) (Aakhus, 2007), and Human-Centered Design (Krippendorf, 2006) as key theoretical concepts for this study

Theoretical concepts, frameworks, and exigencies

In this study, I overlay design oriented communication theories such as CaD and GPT with principles of HCD to show how design mindsets can serve as alternative and important pathways for understanding organizational communication generally and professional formation specifically. A grounded practical theory perspective serves as an entrée point for establishing such new pathways.

Grounded practical theory (GPT).

In order to unpack the embedded communicative and design processes in professional formation I implemented a grounded practical theory (GPT) (Craig & Tracy, 1995) framework to provide a more nuanced description of how dilemmas (and affordances) were manifest in professional formation. As design-oriented theory of communication, GPT is utilized to reveal conflicting goals in the process of becoming a biomedical engineer, the strategies individuals used to overcome these conflicts, and the underlying rationale that guided their decisions. For this study, conflicts or dilemmas were conceptualized as problems that emerged as "communicators pursue[d] multiple, competing goals or purposes such that conflicts among goals often emerge[d] to block ongoing discourse" (Craig & Tracy, 1995, p. 254).

For instance, Bloom (2014) applied GPT principles to interviews conducted with participants of a multilingual, transnational healthcare initiative in Spanish-speaking country. The interactional strategies among English-speaking and Spanish-speaking healthcare professionals were examined as they balanced the dilemma of building rapport with Spanish-speaking patients and efficiently transferring information. Bloom showed that these healthcare professionals developed hybrid translation strategies to overcome the interactional dilemma and suggested this multilingual approach as the underlying normative model.

The use of GPT provided the conceptual and methodological framework to address how discursive practices produced interactional dilemmas alongside the normative ideals that guided the strategies for overcoming dilemmas. GPT is built on the assumption that "communication problems typically arise because communicators pursue multiple, competing goals or purposes such that conflicts among goals often emerge to block ongoing discourse…" (Craig & Tracy, 1995, p. 254). Uncovering the contradictory as well as compatible assumptions within engineering illuminated the possibilities for designing formats that could support what were once considered "irreconcilable or unimaginable forms" (Aakhus, 2007, p. 116) of professional formation discourse. These implications fall squarely in the purview of Communication as Design (CaD) principles.

Communication as Design (CaD).

According to Aakhus (2007), communication design "happens when there is an intervention into some ongoing activity through the invention of techniques, devices, and procedures that aim to *redesign interactivity and thus shape the possibilities for communication*" (p. 112, emphasis added). For the current study, "designs of communication" are conceptualized as formats of professional formation, such as, lecture curricula, lab participation, design projects, and undergraduate research participation. Each format or communication design maintains a particular form of interactivity that shapes discursive practices related to what it means to be an engineer and what engineers should know.

Designs for communication presuppose something about communication, or more specifically to the current study, each design presupposes something about how professional biomedical engineering identity and knowledge is constituted. Merriam-Webster (2019) defines the verb, presuppose, as "an antecedent in logic or fact". Related to CaD, communication designs or format serve as logical antecedents to how communication *ought* to be enacted. As such, and related to the current study, professional formation communication designs presuppose something about how recurrent discursive practices in/by biomedical engineering learners and educators ought to be performed and how recurrent discursive practices constitute professional identity and knowledge in ways that are enabling and problematic.

Interactivity, a critical concept in CaD, shapes and maintains how communication *ought* to work. For instance, Jackson's (1998, 2002) structured online dialogue protocols reconstructed interactivity to facilitate disagreement among students in online classroom settings. The alternative form of interactivity was designed to limit barriers for argumentation such as authority dependence, peer pressure, and passivity. By using the interactivity of online dialogue protocols as a tool for communication design, Jackson was able to produce possibilities of communication that were once difficult or unimagined.

It is important to uncover what interactivity presupposes of communication, discourse communities, and constitutive processes. Doing so elucidates the implications any sort of intentional intervention of interactivity may have for the constitutive forces of professional formation. Principles of Human-centered design (HCD) add an additional layer of design-inspired insight, in combination to GPT and CaD.

Human-centered design (HCD).

HCD is characterized by: the joint participation of those impacted in and by design (i.e., stakeholders), an awareness of processes that lead to (re)constructing social and material realities, and an acknowledgement of communication in the construction of these many realities (Krippendorf, 2006). Communication design, again, "happens when there is an intervention into some ongoing activity through the invention of techniques, devices, and procedures that aim to redesign interactivity and thus shape the possibilities for communication" (Aakhus, 2007, p. 112). This project integrates principles of human-centered design with communication design to illuminate how stakeholders engaged in ongoing and intentional design of and possibilities for communication. Exploring designs for communication brings to life the many human experiences in the active design of interactivity and discourse in an attempt to achieve more desirable and relevant processes of professional formation. This is a process of reconstruction (Craig & Tracy, 1995) and resembles Krippendorf's (2006) suggestion that "communication designers" have a role in reconstructing discourse in an attempt to achieve some desired end. Uncovering the constitutive features of becoming a biomedical engineer and the formats that enabled or constrained professional formation provided a different vision of "humanness" in human-centered design.

Traditional modes of understanding are shifting from what was or is "true" (i.e., science) to also include an emphasis on what can be undone, rebuilt, changed, or constructed (i.e., design as process and product) (Aakhus, 2007; Aakhus & Jackson, 2005; Krippendorf, 2006; Rittel & Webber, 1984; Simon, 1969). As such, it is important to engage in design theoretically, pragmatically, and methodologically for communication scholars, engineering education researchers, and interdisciplinary members (individually and collectively). Design and communication are joined together in important ways.

At the core of design are two fundamental premises: (a) the shift from a current to some other desired state, and (b) what is being (or can be) reconstructed to achieve the desired state. Answers to these questions, and especially in the context of this study, produces apertures for growth and for initiating change. That is, unpacking how stakeholders are reconstructing their social and material worlds elucidates what goals and desired ends they have for their professional formation; the conflicts they experience in reaching these ends; and the opportunities that can be designed to produce innovative change. From a communicative viewpoint, the constant (re)production of social and material realities underscores professional formation processes. Social realities in the context of the current study involved understandings of what it means to be a professional engineer; what knowledge is understood to relevant for professional engineering, and how future engineers *should* be prepared for their professions. Material realities included the organizational, curricular, and pedagogical structures that enabled professional formation.

Focus on the communicative (in this case, discursive) practices of individuals creates an entrée point for understanding how multiple areas of identity, culture, curriculum, and marketplace demands converge in the complex and wicked process of professional formation. This study builds on the emerging, yet limited, body of work that illuminates how individuals communicatively engage in design to (re)conceptualize their worlds (Aakhus, 2007; Krippendorf, 2006). Importantly, there are few studies that overlay design-oriented communication theories such as CaD and GPT with principles of HCD to show how design can serve as an alternative and important pathway for understanding organizational communication generally and professional formation specifically. Communicative assumptions and frameworks such as discourse, GPT, and CaD overlay with design theoretically and methodically to reveal the ways in which stakeholders communicatively construct their social and material worlds – *in addition to*, the normative rationale for doing so. The ultimate outcome includes understandings and design-inspired propositions for how to initiate pragmatic change.

Organizational context

The context for this study involved the professional formation of engineers in a Midwestern university with its own College of Engineering and Schools in which distinct engineering disciplines or programs are housed. The undergraduate setting is a particularly important context for investigating professional formation processes given the National Science Foundation's (NSF) Professional Formation of Engineers (PFE) initiative. The PFE initiative's central mission is "to create and support an innovative and inclusive engineering profession for the 21st Century" (NSF, 2015, para. 1). I investigated the communicative practices and institutional processes that contributed to or inhibited the professional formation of engineers within an undergraduate setting. Specifically, I examined formation processes at a school of biomedical engineering (BME) at a large, Midwestern university.

The BME school is a particularly interesting study site given unique demographic and programmatic characteristics. The undergraduate population at the BME school, on average for recent semesters, has been 44-46% female, where the school of ECE at the same university has been 13-14% female (University Data, 2017). And although BME has slightly more underrepresented minority students (7-8% versus 5%), approximately 60% of BME students are white, versus 40% for ECE (University Data, 2017). These demographic characteristics are important to consider given the possibilities for exploring engineering ontologies, epistemologies, and communication designs that are both enabling and inhibiting inclusionary professional formation.

From a programmatic point of view, the BME school differed from other schools of engineering at the university. One of the most apparent differences was the school's undergraduate cohort model. All engineering undergraduates at the university were enrolled in a first-year engineering program and began their disciplinary program (e.g., BME, ECE) their second year. Following a cohort model, BME students progressed through the same foundational BME courses beginning the first semester of their second year. The cohort model fostered a close-knit community (i.e., approximately 80 students per cohort) given that each new group of students took the same courses at the same times. Each semester followed an overarching topic area, such as, electrical systems, physiology/anatomy, and mechanical principles. These organizational structures are also important to consider given their influence on programmatic design and the impact on how engineering identity and knowledge is situated within this particular school.

Summary and Overview of Chapters

Chapter One described the overarching purpose of the study along with the central exigencies being addressed. The rationale of the study was presented followed by the specific communicative and design approach undertaken. Chapter one also presented the study's research objectives and described the project's metatheoretical, theoretical, and disciplinary commitments.

Chapter Two begins with a general overview of design and design theory emphasizing a paradigm shift from technology-centered to human-centered understandings of design. The contributions of Klaus Krippendorf (2006), specifically to the human-centered shift and the communicative impact in and by design, are then presented. Design epistemology and inquiry is presented next. This section describes the ways in which design is a process for creating useful artifacts as well as a *way of knowing* (Aakhus, 2007; Cross, 2006; Krippendorf, 2006). Design products, people, and processes are presented as sources of design knowledge (Cross, 2006). Communication as Design (CaD) (Aakhus, 2007; Aakhus & Jackson, 2005; Jackson & Aakhus, 2014) is discussed next. The central assumptions of CaD are laid out and I highlight those conceptual aspects of CaD that are most relevant to the current study. Following review of the CaD framework, I present grounded practical theory (GPT) (Craig & Tracy, 1995) and the ways in which this approach contributes to the current project. The central design problem (i.e., issues in/by the professional formation of engineers) is presented alongside the research questions that guide this study:

RQ1: What are discursive practices of professional formation within a school of biomedical engineering?

RQ2 - How does grounded practical theory (GPT) identify conflicting goals in professional formation, strategies for overcoming conflicts, and the underlying rationale for strategies?

RQ3 - How can Communication as Design (CaD) suggest what communication designs presuppose about what it means to be a professional engineer?

RQ4 - How can principles of Human-Centered Design (HCD) elucidate a design stance of professional formation?

These research questions introduced how a design mindset can elucidate alternative and important pathways for understanding organizational communication generally and professional formation specifically.

Chapter Three describes the project's methodology. Participant information is followed by data gathering procedures, including descriptions of the semi-structured interviews data collected. Procedures of data analysis are then presented. Specifically, to address this study's research question, a multi-faceted study design incorporating both empirical and design perspectives was utilized.

Participants for this study included undergraduate students and faculty, staff, and administration (FSA) at a school of biomedical engineering (BME) at a large, Midwestern University. Semi-structured interview data was collected to address RQ1 (for all IRB approvals, see Appendix A). Interview data gathering procedures explored participants' descriptions, accounts, and experiences related to professional engineering formation (Lindlof & Taylor, 2011) in BME (for interview protocol, see Appendix B). Total interviews included 33 total including 15 FSA and 18 student interviews. The study involved an empirical examination of discursive practices that invoked, reproduced, and maintained discourses of professional engineering at the BME school.

Following the constant-comparative method (Lindlof & Taylor, 2011; Maykut & Morehouse, 2001), I developed categories and coding schemes as they emerged from the qualitative data. This inductive process unpacked the various meanings produced by qualitative data, "as each new unit of meaning is selected for analysis, it is compared to all other units of meaning and subsequently grouped (categorized and coded) with similar units of meaning" (Maykut & Morehouse, 2001, p. 134). A constant-comparative approach allowed me to draw connections from qualitative data to discourse-specific concepts, such as, recurrent discursive practices, common vocabularies, and forms of legitimization. This approach also revealed how participants used discursive practices to construct and maintain engineering as a profession; what interactional dilemmas emerged in and by these discursive practices; and what interactivity formats presupposed about communication, and by consequence, the construction and maintenance of engineering ontologies and epistemologies.

GPT is built on the assumption that "communication problems typically arise because communicators pursue multiple, competing goals or purposes such that conflicts among goals often emerge to block ongoing discourse…" (Craig & Tracy, 1995, p. 254). As such, they recommend any GPT endeavor to begin at the problem level–that is, "What are the problems actors face as they seek to communicate appropriately? What concerns do actors themselves have?" (p. 255). Focusing on the problem reveals interactional dilemmas that maintain competing goals, interests, experiences, and so on. At the technical level, the strategies invoked reveal actors' orientations as they attempt to resolve interactional problems. The philosophical level involves identifying "situated ideals"–in other words, the normative principles that serve as reasoning mechanisms for actors' communicative and interactional choices. Craig and Tracy (1995) argue, "Situated ideals may be revealed more indirectly and subtly; they are often implicit in people's descriptions of talk occasions." (p. 259). Addressing these interrelated levels of reconstruction thus generates an idealized model of communication for the professional formation of engineers.

Based on insights gained from the empirical examination of discursive practices, a grounded practical theory (GPT) (Craig & Tracy, 1995) framework was applied to examine conflicts in professional formation, strategies participants used to overcome these challenges, and the underlying rationale for these strategies. GPT revealed overarching goals in professional formation as well as contradictions inherent in the discursive maintenance of professional engineering. Professions, as discourse communities, are brought into life in and by discursive practices (Cooren, 2015). It is important, therefore, to understand interactivity as a constitutive premise in the professional formation of engineers. That is, understanding what interactivity presupposes about communication (Aakhus, 2007) reveals how formats of interactions creates and maintains a discourse of the engineering profession. Interactivity is a design tool for the communicative construction of the professional formation of engineers (Aakhus, 2007).

The first three research questions focused on (a) how the engineering profession is discursively maintained, (b) the tensions, contradictions, and problematics found in professional formation, and (c) interaction formats and what they presupposed about professional formation. Human-centered design (HCD), elucidating the multiple human experiences of immediate stakeholders, acknowledges and brings forth the need to identify and (re)construct the social worlds in the process of design (Krippendorf, 2006). In other words, a human-centered design enterprise asks, what are the many social and material worlds present in a specific community?

And how are these worlds communicatively constructed and maintained? The response to these questions generates an understanding of the current conditions of some problem space as well as some other desired end. The design stance of this study illuminated the processes by which members of biomedical engineering communities attempted to realize preferred professional ontologies and epistemologies. The human-centricity involved in intentionally (re)designing individuals' discursive environments provided implications for and suggested a different view of "humanness" in human-centered design.

Chapter Four includes the study's findings. Findings follow the grounded practical theory framework and presents the overarching goals of professional formation, as revealed by participants' descriptions. Specifically, the goal of gaining a broad knowledge base–incorporating expertise across various engineering and science disciplines–often can come at the expense of realizing specific application and technical know-how. For many participants, both goals were critical for becoming a professional biomedical engineer but often times blocked a discourse of professional formation that was innovative and inclusive. Participants revealed that a standard lecture curriculum influenced this tension, in many cases for the worse. However, findings suggested that strategies for overcoming these conflicts were by integrating lecture curricula with more active learning formats (e.g., undergraduate research, lab participation). The outcome was cultivating a broad knowledge base *while also* building on specific technical know-how. The philosophical rationale for investing in these strategies of professional formation resembled situated learning models (Lave, 1988; Lave & Wenger, 1990; Brown, Collins, & Duguid, 1989) where context, community, and participation were equally relevant as factual and procedural knowledge.

Moreover, findings showed how standard lecture communication designs shaped and maintained a discourse community more likely to emphasize understanding engineering as a science and also gaining a broad knowledge base often times at the expense of realizing specific application and technical know-how. The result was a "jack-of-all-trades" professional biomedical engineering identity that was devalued by many in the biomedical engineering community and viewed as problematic for equipping and preparing future biomedical engineers. Following the GPT framework, lecture designs were identified as a barrier for realizing practice-oriented goals of engineering professional formation—in contrast, to theory-oriented goals of professional formation. Specifically, and from a methodological perspective, statements of praise and criticism of professional formation designs (e.g., lectures) were used as criteria for identifying communication designs that either inhibited or enabled realizing goals of professional formation. However, findings also revealed that designs for communication resembling situated learning characteristics (Lave, 1988; Lave & Wenger, 1990; Brown et al., 1989; Stein, 1998) lead to recurrent practices that embraced the breadth of biomedical engineering's knowledge base while also contributing to ongoing technical skills development and application. These practices shaped a biomedical engineering identity that was viewed to be more aligned with an increasingly competitive professional marketplace, a marketplace that demanded being broadly-based while also maintaining specific technical competencies.

Chapter Five provides a discussion of this study's theoretical contributions, study limitations, and practical implications. In this chapter, I first discuss (a) theoretical contributions, highlighting how this study contributed specifically to GPT, CaD, and HCD. I then (b) describe some of the study limitations, followed by (c) theoretical implications and future research directions. This study's (d) practical implications come next and involve the (1) implications for professional preparation, diversity, and inclusion, (2) design criteria for professional formation of engineers, and a (3) design roadmap for implementation. I conclude with a brief summary of the chapter and the overall dissertation project.

CHAPTER 2: LITERATURE REVIEW

This chapter highlights the central theoretical concepts of the current study. I begin with a description of (a) design frameworks and design rationality and (b) differences between technology-centered and human-centered perspectives of design. I turn to (c) Krippendorf's (2006) semantic paradigm of human-centered design (HCD) and its communicative implications. Next, I discuss (d) three epistemological principles of design. That is, I describe how design mindsets can serve as an alternative pathway for understanding. I follow epistemological contributions of design with an (e) overview of Communication as Design (CaD). The CaD overview involves three central assumptions along with two strategies for developing a CaD enterprise. I then highlight (f) the main elements of grounded practical theory (GPT) and conclude with a (g) summary of research questions.

Design frameworks and design rationality

"Design brings forth what would not come naturally" (Krippendorf, 2006, p. 25)

In simple terms, Krippendorf's statement describes the essence of design. Design is realizing some ideal, desired, or preferred state. Design exists in a generative tension between what is true, what is real, and what is ideal (Jackson & Aakhus, 2014; Nelson & Stolterman, 2012). Traditional scientific approaches (i.e., the scientific method) suggest what is true and real, whereas, design emphasizes what is ideal. Simon's (1969) *Sciences of the Artificial* has been attributed for developing modern era understandings of design and artificial intelligence. Simon states, "everyone designs who devises courses of action aimed at changing existing situations into preferred ones" (p. 111).

There are differing perspectives regarding design's role in and potential for (a) problem solving and (b) knowledge creation. Rittel and Webber (1973, 1984), for instance, differ from Simon in their view of design rationality. Following a purely Simonian stance reduces design to problem-solving based in a scientific technical rationality (Krippendorf, 2006). As Rittel suggested, technical rationality is well-suited for "tame" problems where issues and possible solutions are well-defined (Rittel & Webber, 1973, 1984). Technical rationality is ideal for scientific projects aimed at confirming "factual" statements of what is "true". However, design rationality is not so much concerned with what "is" or what "was", but rather what "should be" – a shift from a purely empirical to a normative enterprise. That is, the normative dimensions of design (i.e., what "should be") account for the complex, and often contradictory, social and human experiences involving individual goals, systemic and/or structural affordances and constraints, micro and macro identity structures, and individual and global value sets. Rittel and Webber describe (1973, 1984) issues involving these multiple, intersecting layers as *wicked problems*.

For Rittel, wicked problems are issues constituted by and involving multiple and interrelated human experiences. For instance, poverty is commonly referred to as a wicked problem (Hayden & Jenkins, 2014; Head & Alford, 2015; Rittel & Webber, 1973), an issue that involves many underlying and constantly shifting causes and consequences (e.g., access to education, lack of skills, inequality, inadequate housing, poor healthcare, inefficient infrastructure). Linear approaches have resulted in ineffective and costly policy decisions (See Spicker, 2017 for a discussion of poverty as a wicked problem). That is, approaching poverty as a problem that can simply be "solved" by "fixing" singular causes typically does not account for how factors of poverty, in fact, shift during attempts at solving.

Wicked problems frequently shift and are never "solved" in a traditional sense. Problems may be temporarily resolved but manifest again under different circumstances and in different formats (Krippendorf, 2006). As such, the logic of design underscores how solutions are understood, accepted, and used by stakeholders whose experiences and interests are immediately connected to the problem at-hand.

Technology-centered or Human-centered design

In today's design landscape, there is *not* a dearth of models for design. There are hundreds of models with unique points of emphasis and an equally diverse number of stages, phases, and steps (for a critique of contemporary engineering design models, see Maffin, 1998). For a good portion of the design mainstream, design models have emphasized *functionality* adhering to the longstanding maxim–*form follows function*. These functionalist versions of design are typically technology-centered.

Most design models can be broadly categorized as either technology-centered or as human-centered models for design. Table 1 offers an adapted visual that provides a side-by-side comparison of the key distinctions between technology-centered and human-centered views of design. The term "technology" is used here as a general descriptor. The Greek definition of the terms comes from *technologia* or the "systematic treatment of an art" (Merriam-Webster, 2017). Essentially, technology is the skill of accomplishing some set of objectives. Thus, any process or product aimed at accomplishing some objective could be described as a technology. That said, technology-centered views of design are typically focused on the product and its functions, they tend to ignore situated context, and derive functions based on understanding the past (Krippendorf, 2006). For instance, traditional mechanical engineering could be categorized as a technology-centered approach to design (for a review of mechanical engineering design, see

Shigley, Mischke, & Budynas, 2004). Mechanical engineering design typically establishes pre-determined steps for design, the specifications necessary to realize these steps, and optimization methods to determine the feasibility of the design – identifying all possible constraining variables in the optimization process.

Human-centered design models, by contrast, maintain different emphases. Human-centered design:

> …recognizes the human involvement in the artifacts of design, acknowledging not only that designers are humans, communicate with others through and about the technology they develop, and participate in the social constitution of reality, but also that all those affected by technology bring their humanness to bear on what they do with it. (Krippendorf, 2006, p. 40)

Of particular importance is the communicative emphasis in "the construction of diverse community-specific worlds" (p. 40). Human-centered design, through joint participation of various stakeholders, acknowledges and brings forth the need to identify and (re)construct the social worlds in the process of design. In other words, a human-centered design enterprise asks, *what are the many social and material worlds present in a specific community?* And *how are these worlds communicatively constructed and maintained?* The response to these questions generates an understanding of the current conditions of some problem space as well as the idealized or preferred state.

Although HCD in theory acknowledges the role of language, very few HCD projects take an authentic communicative stance to design. As such, HCD projects lack a conceptual understanding of *how* community-specific social worlds are constructed and maintained—an undertaking particularly well-suited for a communicative stance to human-centered design.

Table 1: Dimensions of Design Technology-centered vs Human-centered

Technology-centered	*Human-centered*
The design of products	The design of artifacts that can play various social roles
Belief in technological progress	Concern for artifacts that are supportive of communities of users and are user-friendly for their individual members
Universal and culture-free conceptions of design in a (single) universe	Acknowledgement of the role of language in the construction of diverse community-specific worlds
Imposing intended functions of products, enforcing particular uses through training/certifications	Allowing people to use designs in their own terms
Designers as lone genius or authority	Designers who work in teams, including users, and are able to enroll stakeholders of their designs in joint projects
Attention to objects, products, material artifacts (ontology)	Awareness of the processes of (re)constructing artificial worlds whose sole purpose is to design artifacts that make sense, that are useful, and welcoming for stakeholders

Adapted from: Krippendorf, K. (2006). *The semantic turn: A new foundation for design*. Boca Raton, FL: Taylor & Francis.

From an applied perspective, there are many organizations that embody and promote human-centered design. The design firm, IDEO, has developed a prestigious reputation for adhering to a human-centered design process (see Figure 1). Their projects range from community-based, healthcare programs to innovation in education (IDEO, 2019). For IDEO, "Human-centered design offers problem solvers of any stripe a *chance to design with communities*, to deeply *understand the people* they're looking to serve, to dream up scores of ideas, and to create innovative new *solutions rooted in people's actual needs*" (IDEO field guide, 2015, p. 9, emphasis added).

IDEO suggests design is more than a process but also a series of mindsets or philosophies. These mindsets include: learn from failure, make it, creative confidence, empathy, embrace ambiguity, optimism, and iterate, iterate, iterate (IDEO, 2019). IDEO's process of design, alongside design mindsets, illustrates a design rationality situated in a logic of failure, mutual constitution, and complexity. Many of IDEO's design commitments underscore the social complexity of design and by so doing create space for the multiple social realities involved in the process of design.

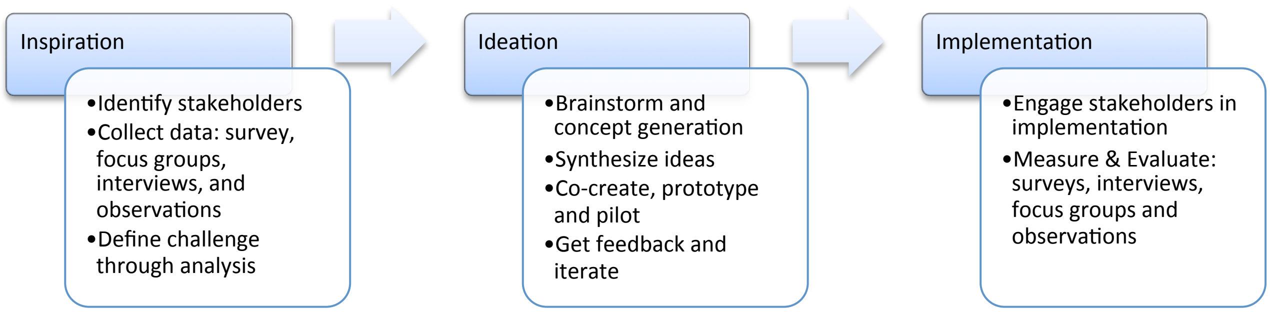


Figure 1: IDEO design process (Open source: www.designkit.org)

For purposes of this study, it is important to understand the underlying philosophy and assumptions of human-centered to deeply root this study's orientation and add texture to the process of changing from a current state to some preferred other state. And bring to life the many human experiences and points of view that are involved in this process.

Krippendorf's (2006) semantic turn of design provides an added and meaningful layer for human-centered perspectives of design. The following section highlights Krippendorf's contribution to HCD specifically highlighting the increasingly involved role of language in/by design. Ultimately Krippendorf suggests that "communication designers" have a role in reconstructing discourse in an attempt to achieve some desired end state.

Krippendorf's semantic paradigm of design

Klaus Krippendorf was a significant contributor to the human-centered paradigm shift. Much of his research examines the consequences of language and the social constructions of social, technical, and material realities (Krippendorf, 2016). His influence and contributions are important to address due to the communicative implications he brings forth in and by design. Human-centeredness for Krippendorf is:

> …a move from the image of humans as having to adapt to technological progress and of designers as making adaptation less painful, to the image of humans as able to influence the direction of technological development and of designers as finding ways to support diverse practices of living, community, and the sense needed for individuals to feel at home…the acknowledgement that meaning matters. (p. 13)

Thus, Krippendorf brings the constitutive power of communication and the generative function of meaning to the core of design theory.

Krippendorf's (2006) "the trajectory of artificiality" (see Figure 2) describes the shift from a functionalist notion of design (i.e., technology-centered) to increasingly social and communicative considerations for design. At the beginning point of the trajectory, designs maintain a purely functionalist rationality where design considerations are solely based on the industrial and mass production of an artifact. Krippendorf argues that a primary emphasis on functions is problematic, he states:

> It does not question what they [functions] are to serve, where functions come from, and the legitimacy of those who define them for designers to start with. It signals designers' blind acceptance of the role they are assigned by society and by their industrial employers in particular. (p. 5)

A stable, functionalist view of society, as Krippendorf argues, does not reflect the social complexity of modern society and as such, design must be able to extend its considerations. Thus, the trajectory of artificiality is a progression of design with each new phase extending and adding new design considerations and criteria.

Importantly, as the trajectory progresses design considerations become increasingly reliant on language and the constitutive forces at play. For instance, interfaces are predicated on the mutuality of human and machine (e.g., the human-computer interface). Design must take both into account. Systems are built on the ability for individuals and users with systems to organize and use the information around them. Projects are ultimately constituted by how individuals talk about, value, and prioritize what is important—in other words, "projects are realized in particular communicative practices among participants" (p. 10). The trajectory of artificiality illustrates the evolution from functionalist considerations to the generative power of language and communication in and by design (Krippendorf, 2006).

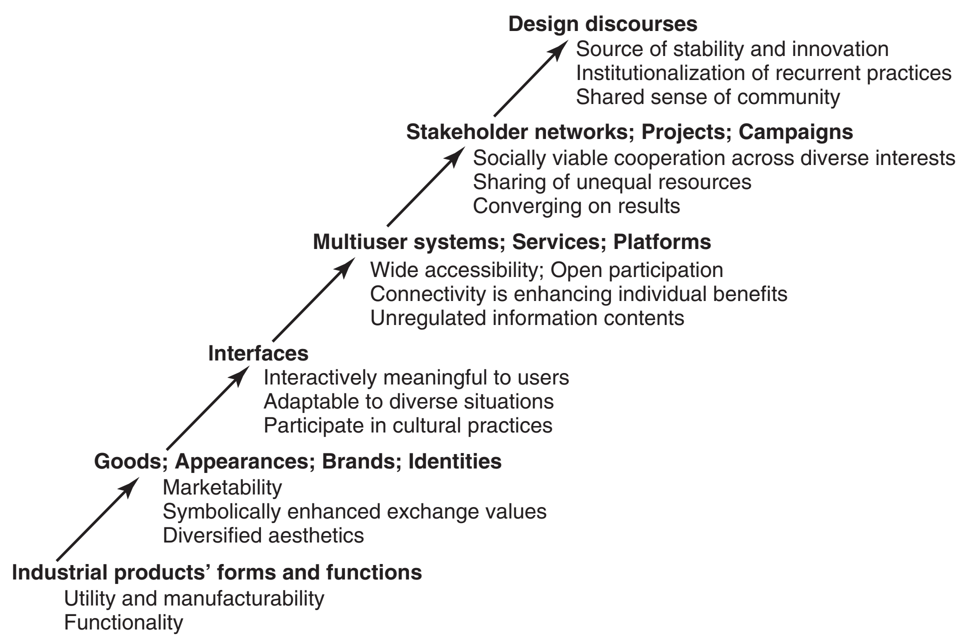


Figure 1 A trajectory of artificiality and its guiding design criteria.

Reprinted from Krippendorf, K. (2006). *The semantic turn: A new foundation for design*. Boca Raton, FL: Taylor & Francis group. Copyright 2006 by Taylor & Francis Group.

Figure 2: Krippendorf's Trajectory of Artificiality.

At the extreme of the trajectory, Krippendorf introduces discourse as a design consideration. Discourse(s) "are organized ways of talking, writing, and acting accordingly…discourses reside in communities of people who collaborate in enacting what constitutes their community…organizes their actions, and construct(s) the worlds they see" (p. 11). Discourse, constituted in language and communication, is open to new vocabularies and ways of talking and acting. As such, discourse is difficult to design, in the traditional sense expressed by Krippendorf (2006). However, individuals can intentionally change and encourage new practices, new vocabularies, new descriptions, new conversations—ultimately, "new ways of conceptualizing the world" (Krippendorf, 2006, p. 12).

An important consideration for the current study is the discursive construction and maintenance of biomedical engineering as a profession and its implications for professional preparation as well as for matters of diversity and inclusion. Professional communities, such as engineers, medical doctors, lawyers, and professors, are maintained by their discursive practices (Cooren, 2015; Krippendorf, 2006). Krippendorf (2006) states:

> All discourses—scientific, legal, medical, public, and private—not only converge on specialized vocabularies, they also specialize in constructing discourse-specific realities, artifacts, whether they be predictive theories, legal judgments, medically treatable illnesses or disabilities, elected representatives, or family secrets. Discourse communities organize themselves by institutionalizing recurrent discursive practices, legitimizing methods, and encouraging the emergence of social hierarchies of offices, experts, and privileges. All of these well-known features of discourses limit the freedom experienced in conversations while expanding the scope of their practitioners' accomplishments. (p. 9)

Given Krippendorf's comments, "communication designers" have a role in reconstructing discourse in an attempt to achieve some desired end state. In terms of this study, the aim is how stakeholders reconstruct a discourse of engineering that is integrative of both social and technical aspects of engineering creating more inclusive environments and preparing future engineers to deal with the social complexities of their careers. Reconstructing a discourse of engineering involves addressing the rules of interaction, typical recurrent practices, and legitimate methods of conduct (Krippendorf, 2006, 2016).

Similar to Krippendorf, Nigel Cross (2006) introduced how design can be used as alternative pathways for understanding. Cross specifically points to the epistemological foundation and contributions of design rationality. In the following section, I lay out three principles of design as epistemology. These design epistemology principles include: (a) principle one which suggests design knowledge is gained in understanding the individual elements of a design, the goal of the design, and how the design achieves its goal; (b) principle two recommends designers should be reflective practitioners which underscores how design is enacted and communicated can shape what is known and what can be known about design; and finally, (c) principle three suggests that knowledge is produced in understanding the move(s) from a current state to some other preferred state or ideal, in other words, understanding is created by being reflective of design methodologies. Each principle provides an alternative framework for understanding the multifaceted and complex nature of professional formation. Each design principle creates space for understanding the goals of professional formation, the various intersecting factors involved in professional formation, and how stakeholders attempt to reach these goals, navigating through real or perceived constraints and affordances.

Design as epistemology

Another significant contributor to design theory, Nigel Cross (2006), argues knowledge is obtained in the process of changing or reaching some desired end—in other words, knowledge is obtained in and by design. He argues that design knowledge can be found in three sources: products, people, and processes. Jackson and Aakhus (2014) expand Cross' definition, they argue "the knowing is in the artifacts created, the creative activity of designers, and the processes of manufacturing artifacts" (p. 127). These sources can also be conceptualized as principles for design inquiry. Given this study's design orientation, it is important to highlight design epistemology as the knowledge created in the process or reaching some desired end. In this study, I highlight the process by which members of a biomedical engineering discourse community intentional (re)design their discursive environment, through investing in certain formats of professional formation. Illuminating this process builds on design as epistemology.

Principle 1

Simon (1996) suggests any design enterprise should involve an understanding of, (a) the organization of an artifact, and (b) how the artifact accomplishes a desired end (Aakhus, 2007). Thus, design knowledge is gained in understanding the individual elements of a design, the goal of the design, and how the design achieves its goal (Harrison, 2014). From a communicative perspective, following this principle involves what is known about particular discursive practices, who performs these practices, how they use communication, and under what circumstances. The second principle of design inquiry draws attention to the creative activity of designers and the design practice itself (Cross, 2006; Jackson & Aakhus, 2014).

Principle 2

Schön (1984) suggests that designers should be reflective practitioners. As reflective practitioners, designers should consider the discourse of design and what affordances a design discourse provides in terms of what is known and what can be done in design (Krippendorf, 2006, 2016). The design language used, the design research enacted, and the design principles employed contribute to a design discourse that define design education and the design profession

(Krippendorf, 2016). From an epistemological sense, how design is enacted and communicated can shape what is known and what can be known about design.

Importantly for the current study, as reflective practitioners, designers also produce an understanding of the creative activity of designers. Understanding of designers involves concerns, such as, how do those “in a position to shape communication do to shape it” (Aakhus, 2007, p. 117). What principles, commitments, knowledge premises, identities are called upon in the creative process of designing? A communicative design stance is particularly well-suited to address these concerns. A communicative approach to design reveals the communicative construction process in and by design. Jackson and Aakhus (2014) suggest “a design stance calls attention to what is created (designed artifacts) and how it is created (design work)” (p. 129). The third principle of design inquiry calls attention to the design work.

Principle 3

The third principle of design inquiry considers the process of design—in other words, being reflective of design methodologies (Aakhus, 2007; Jackson & Aakhus, 2014; Jones, 1992). Design knowledge is produced in understanding the move(s) from a current state to some other preferred state or ideal. Being reflective about design methodology also improves and creates an understanding how to design in the future. As Jackson and Aakhus (2014) argue, “at the very least, in designing, we improve our knowledge of how to design” (p. 129).

Unsuccessful design inventions contribute to design knowledge in equal manner as “successful” inventions. Aakhus (2007) argues, “A design enterprise focuses on invention and the accumulation of practical knowledge embodied in successful and unsuccessful design and the continuous refinement of processes for design.” (p. 115). For instance, Sprain, Carcasson, and Merolla (2014) illustrated how an unwanted use of a communication design (i.e., a deliberative procedure for utilizing expertise into public deliberation) informed the possibilities of reconstructing communication strategies in deliberation (Jackson & Aakhus, 2014).

Design knowledge departs from traditional social-scientific approaches following a propositional format—that is, developing theoretical propositions to empirically test. Design *researchers* are concerned with what *should* or *could* be while traditional social scientists are interested in explaining how the social world works. Therefore, design is not simply a process of creating new and useful things (Aakhus, 2007; Aakhus & Jackson, 2005) but also an intellectual enterprise – a *way of knowing* (Cross, 2006; Schön, 1984; Walters, 1986).

Communication as Design (CaD)

Aakhus and Jackson (Aakhus, 2007; Aakhus & Jackson, 2005; Jackson & Aakhus, 2014) have been at the forefront of developing a communication stance for design introducing Communication as Design (CaD). According to Aakhus (2007), communication design "happens when there is an intervention into some ongoing activity through the invention of techniques, devices, and procedures that aim to *redesign interactivity and thus shape the possibilities for communication*" (p. 112, emphasis added). Possibilities for communication in this sense involve the communicative practices that emerge as individuals attempt to resolve issues of meaning, action, and coherence (Jacobs, 1994) within particular interaction formats. Possibilities for communication also draw attention to how communication *ought* to work within certain interaction formats.

The following section introduces three core CaD assumptions. The first assumption argues that (a) design is a natural fact of communication; the second assumption present (b) designs for communication are hypotheses and describes the important role of interactivity; and the third assumption considers (c) communication design as theoretical.

CaD assumption: Design is a natural fact of communication.

A central assumption of CaD is *design is a natural fact of communication*. Design is a natural fact of communication insofar as individuals design their communication as they resolve *communication puzzles* (Jacobs, 1994) of "meaning (how is it that people convey and infer meaning in saying something?), action (how is it that people do things with words?), and coherence (how is it that people coherently coordinate meaning and action?)" (Aakhus, 2007, p. 113). Aakhus (2007) argues that the grounds for communication design exist in the patterns of communication that emerges as individuals attempt to resolve these communication puzzles. Through and by their communication, individuals design their interactions as they make sense of and attempt to resolve problems in communication.

CaD assumption: Designs for communication are hypotheses.

A second assumption of CaD is that *designs for communication are hypotheses* for how communication ought to work. Any number of interaction formats presupposes something about communication (Aakhus, 2007). Given affordances and constraints, interactivity shapes and maintains how communication *ought* to work. Communication design work happens when individuals intervene in communication practices to realize preferred forms (Aakhus, 2007).

Interactivity

Interactivity is a fundamental element of CaD because it presupposes something about communication. Aakhus (2007) states "design is evident in the way people mutually construct conversation moment-by-moment and turn-by-turn as a form of interactivity through their use of language" (p. 113). A general definition of interactivity includes "the process of two people or things working together and influencing each other" (Oxford Dictionary, 2019). In other words, and in the context of CaD, individuals shape how to work together and influence one another through the mutual construction of their conversations. For instance, the interactivity of entertaining presupposes how communication *ought* to work as compared to the interactivity of business negotiating. Interactivity of entertaining could be constituted by more free-flowing sequence of actions while interactivity of negotiating, at least in professional contexts, may adhere to a more structured sequence. Each format of interaction presupposes how communication ought to work differently then from the other.

Aakhus (2007) suggests that "people construct and sustain forms of interactivity by taking on and displaying for others particular identities, performing particular actions, sequencing actions, and making particular commitments" (p. 113). It is important to note the recursive nature of interactivity and communication in that individuals sustain forms of interactivity in their performance and identity displays, while interaction formats (e.g., curriculum designs) equally promote and suggest how these performances and identities are enacted. Thus, unpacking the nature of interactivity is a critical element of communication design, generally, and the professional formation of engineers, specifically.

For instance, Jackson's (1998, 2002) examination of structured online dialogue protocols presented how refined discourse designs can facilitate argumentation skills among online discussion groups (i.e., interactivity). Jackson compared idealized models of argumentation, following principles of normative pragmatics—a method of empirical discourse analysis—with actualized communication practices. As Jackson (1998, p. 4) argued:

> Comparison of communication practices with the ideal model may uncover discrepancies between real and ideal discourse, whether because in real discourse people face paradoxes that force departure from one ideal or another, or because real discussants have deficiencies in competence, or because of other situational or dispositional constraints.

One particular example Jackson introduces is the Mazur learning protocol developed by a Stanford professor for the purpose improving learning in comparison to traditional lecture teaching methods. Jackson isolated three distinct design features of the Mazur sequence and presented how these features structured discourse and interactivity in the context of learning and problem-solving. The three features included: structuring of talk time, distribution of authority, and orientation to disagreement (Jackson, 1998). She describes how these protocols designed discourse and interactivity to limit barriers for argumentation such as authority dependence, peer pressure, and passivity:

> The Mazur protocol *structures talk* [emphasis added] as a dialogue rather than as the monologue of the lecture that leads up to the problem. *Authority* [emphasis added] is equally distributed between the two partners engaged in the sequence, whereas authority is very unequally distributed between the lecturer and the listeners in any subsequent discussion. Finally, the Mazur sequence is *explicitly oppositional* [emphasis added] and oriented to testing ideas against other, divergent ideas; in a standard question/answer sequence within a classroom, discrepancies between the lecturer's answer and the student's answer are resolved through correction rather than through mutual efforts at persuasion.

Each feature was identified as intentional designs into interactivity. In the Jackson's case, designs of argumentation, problem-solving, and ultimately discourse. The Mazur protocols served as intentional designs to produce possibilities of communication that were once difficult or unimagined.

Specifically, and in terms of the current study, why is interactivity important? Professions, as discussed, are communicatively constituted. That is, professions as discourse communities, are brought into life in and by the communities' many discursive practices. It is important, therefore, to understand interactivity as a constitutive premise in the professional formation of engineers. What do various formats of interaction presuppose about communication? And how is communication, in this sense, constitutive of what it means to be and do engineering? Interactivity is a design tool for the discursive constitution of the professional formation of engineers.

CaD assumption: Communication as Design is theoretical

A third and final assumption is *Communication as Design is theoretical* (Aakhus, 2007). CaD is theoretical in design's ability to be reflective. CaD is reflective about "the successes, failures, and surprises of designs and design work provide material for reflecting upon and theorizing communication" (Aakhus, 2007, p. 115). That is, a CaD enterprise reflects on communication design hypotheses and communication design work and their implications for communication theory and communication concepts. The accumulation of knowledge exists by the successful and unsuccessful designs and what these designs say about communication theory. Additionally, the failure logic of design also serves as a critique of and for the unintended consequences of design (Harrison, 2014). That is, designs for communication produce unanticipated consequences and these consequences suggest something about communication theory.

For example, Harrison (2014) examined the experiences of student disputants as they engaged with a communication design–a university ombudsman process for dispute resolution. Harrison conducted interviews about the grievance process with students who had made a grievance against a faculty member and also with Ombudsmen. Student interviews focused on "the nature of their conflict, their relationships with the faculty member, their reasons for pursuing the grievance, and other questions that helped establish the particular context…" (Harrison, 2014, p. 3). Ombudsman interviews involved "the nature of the process, including specific goals, processes, strategies, and values…" (p. 4).

According to the Harrison, the goal of the interviews was to identify design elements involved in the grievance process, within the specific context. As he stated:

> Gathering accounts from both the ombudsman and the students allowed for a systematic critique of how the enactment of the design functioned in accomplishing the goals of the system…this ombudsman system was designed to help resolve grievance between students and faculty and to reduce litigation against the university.

Thus, Harrison study focused on how real communication practices met or diverged from the idealized goal of the grievance process design. One of the strategies used by the ombud included a delay tactic for cases when they felt the need to "cool out" disputants. This particular communicative strategy, as an element of the grievance design, resulted in unintended consequences. Harrison found that students "felt the ombud was delaying the resolution of their problem and interpreted the ombuds office as having little power, organizational bias, and little desire to help the students" (p. 139). Although students felt that the ombuds were not particular sensitive or able to help reconcile their disputes, a goal of the grievance design, Harrison did find that this process did in fact restore trust in the university. A sense of regained trust, albeit an unintended consequence, was a desired outcome by the university and thus by taking a design approach, identifying unintended consequences improved communication design knowledge for advancing how to better develop dispute resolution processes.

Ultimately, as a theoretical enterprise, communication design tells a communication story and illustrates how communication unfolds in a particular context, what succeeded, what failed, and why. Communication design produces design and practical knowledge for communication theory and for praxis by showing how communication unfolds in society (Aakhus, 2007). Praxis in this sense based in the "systematic normative reflection to inform practical conduct (Craig & Tracy, 1995, p. 249). As Aakhus argues, "a design enterprise…recognizes that theoretical concepts and principles do not translate into practical courses of action in straightforward or predictable ways." (2007, p. 115). The value of communication design resides in an enterprise's ability to advance practical knowledge by the intentional design of communication (Aakhus & Jackson, 2005). Ultimately, communication design "depends on assumptions about how communication works and how it ought to work. A theoretical design enterprise seeks to improve those assumptions so that inventions and interventions can improve on practice" (Jackson & Aakhus, 2014, p. 131).

Two strategies for developing a CaD enterprise.

The following section describes the possible ways to develop a Communication as Design enterprise. The first strategy builds on current communication theoretical knowledge and methodology to intentionally intervene into some communication practice in attempt to reach some preferred or desired end. The second strategy focuses on taking a design stance on empirical analysis, involving; (a) observing affordances and constraints of a particular design and then reconstructing what the design presupposes about communication (Aakhus, 2007), and (b) a design stance in the empirical analysis of communication is to examine the process of communication design.

Strategy #1

Aakhus (2007) describes two overarching strategies for conducting CaD research. The first approach involves engaging in communication design. According to Aakhus, doing communication design research is "reflective engagement with a circumstance using communication concepts and methods to figure out how to make forms of communication possible that were once difficult, impossible, or unimagined" (p. 116). In other words, this line of CaD research builds on current communication theoretical knowledge and methodology to intentionally intervene into some communication practice in attempt to reach some preferred or desired end.

Engaging in communication design research can be accomplished either by creating communication tools or developing design methodologies. Communication tools in this sense refer to communication products that are used to aid or facilitate an identified communication problem. Jackson's (1998) online dialogue protocols are examples of a communication tool used to facilitate a communication problem – in Jackson's case, facilitating argumentation in online learning settings. The ultimate goal of the current research project's design sessions will be to develop some tool that can advance and contribute to a socio-technical understanding of engineering (see Bucciarelli, 1984; Trevelyan, 2007, 2010).

Design methodology involves the creative process of design, following a specific rationality, encompassing both empirical and normative functions (Aakhus, & Jackson, 2005; Jones, 1992). Aakhus and Jackson (2005) describe design methodology as:

> …a framework for the activity of the designer and for making theoretical use of the results of design activity. A design methodology is not a set of methods for data collection or analysis, but a *strategy for operating in any domain from an explicit design stance*…design methodology highlights where the distinctive discourse design expertise…can be brought to bear in the design process. (p. 422, emphasis added)

Jackson's (1998, 2002) normatively-pragmatic design methodology is an example of a communication design methodology. Jackson's methodology includes an "empirical examination of discourse practices, a critical analysis based on comparison of practices with an ideal model, a specification of designable features, and a proposed redesign" (Aakhus, 2007, p. 116).

Strategy #2

The second strategy Aakhus (2007) presents includes taking a design stance in the empirical analysis of communication. This strategy focuses on "how forms of communication that were once difficult, impossible, or unimagined came to be. The aim is to understand how communication design happens and with what consequences" (p. 116).

One approach for a design stance in the empirical analysis of communication explores affordances and constraints of designs for communication. CaD research takes the observed affordances and constraints and then reconstructs what the design presupposes about communication (Aakhus, 2007). In other words, how is the observed design for communication structuring what communication is and is doing? For instance, Barbour and Gill (2014) integrated grounded practical theory (Craig & Tracy, 1995) and communication design assumptions to examine communication designs in daily nuclear plant safety meetings. They reconstructed communication designs and the situated ideals that guided these communicative practices thus advancing knowledge of communication designs in daily safety meetings.

An additional approach for a design stance in the empirical analysis of communication is to examine the process of communication design. That is, to examine how communication design works. Aakhus (2007) states that this research:

> …articulates the tools, ideals, and knowledge of intervention work and then reconstructs the practical theory of communication evident in the conduct of intervention. Of particular interest is what people in a position to shape communication do to shape it and what knowledge and practices are cultivated in various professions and organizations. (pp. 116-117)

Harrison's (2014) study of the ombudsman process describes generally what a design stance in the empirical analysis of communication looks like. Harrison's work illustrates important features, such as, identifying the goals of the object system (i.e., system of dispute resolution at the university), the ways individuals enact the system (i.e., resolution process), and the experiences as individuals use the system (i.e., some disputants viewed the process as fair while others viewed the ombuds office as biased and having littler power).

This current study is situated moreso in taking a design stance on empirical analysis. Leveraging the normative, pragmatic power of grounded practical theory I uncovered the goals for professional formation within a biomedical engineering discourse community, the affordances and constraints for achieving these goals, and the ways in which the discourse community engaged in design to achieve a more preferred state. I provide texture to this process by framing and highlighting this process as a mode of human-centered design—that is, discursive construction, maintenance, and redesign is rooted in human experiences and material realities (e.g., formats of professional formation).

Grounded practical theory (GPT)

Any design enterprise requires an idealized model of some desired end. Grounded practical theory (GPT) (Craig & Tracy, 1995) provides such a model. GPT involves the normative concerns of design, the practical orientation of communication theory, and the utility of any applied program of research. GPT provides the conceptual and methodological framework for developing an idealized model of discourse. GPT is particularly well-suited for developing an idealized model for communication design based on its emphasis on situated communication practices and the practices underlying, guiding normative ideals.

"Theoretical reconstruction" represents the normative dimension of a GPT approach. Reconstruction, according to Craig and Tracy (1995), involves *idealizing* specific communicative practices in more universal terms. That is, in and by reconstruction, the reasoning mechanisms for certain communicative practices are revealed. Craig and Tracy (1995) argue, "the purpose of…reconstruction is not to discover some inherent, unchanging 'essence' but rather to construct a tentative, revisable, but still rationally warranted normative model that is relevant to a broad range of practical situations" (p. 252).

Craig and Tracy (1995) present a problem-centered model for grounded practical theory. The GPT framework involves three theoretical and interrelated levels (see Table 2) and includes specific questions to consider in the reconstruction of communicative practices.

Table 2: Grounded Practical Theory levels of theoretical reconstruction

The technical level	A practice can be reconstructed as a repertory of specific communicative strategies and techniques that are routinely available to be employed within the practice.
The problem level	A practice can be reconstructed as a problem logic or interrelated web of problems that practitioners experience and that bring forth both normative reflection (at the philosophical level) as well as strategic action (at the technical level).
The philosophical level	A practice can be reconstructed in the form of elaborated normative ideals and overarching principles that provide a rationale for the resolution of problems. In reflecting on what to do about a problem, alternative "situated ideals" may be available from which to derive reasons for resolving the problem in one way or another, accepting certain trade-offs among competing goals, and thus choosing to use certain communicative strategies and techniques rather.

Adapted from: Craig, R. T., & Tracy, K. (1995). Grounded practical theory and the case of intellectual discussion. *Communication Theory, 5*, 248-272.

The levels of reconstruction provide a systematic method for theoretical reflection of how individuals experience communicative problems, the strategies used to resolve them, and the ideals that serve as logic mechanisms for these strategies.

GPT is built on the assumption that "communication problems typically arise because communicators pursue multiple, competing goals or purposes such that conflicts among goals often emerge to block ongoing discourse…" (p. 254). As such, they recommend any GPT endeavor to begin at the problem level—that is, "What are the problems actors face as they seek to communicate appropriately? What concerns do actors themselves have?" (p. 255). Focusing on the problem reveals interactional dilemmas that maintain competing goals, interests, experiences, and so on. At the technical level, the strategies invoked reveal actors' orientations as they attempt to resolve interactional problems. The philosophical level involves identifying "situated ideals"—in other words, the normative principles that serve as reasoning mechanisms for actors' communicative and interactional choices. Craig and Tracy (1995) argue, "Situated ideals may be revealed more indirectly and subtly; they are often implicit in people's descriptions of talk occasions." (p. 259). Addressing these interrelated levels of reconstruction thus generates an idealized model of communication for the professional formation of engineers.

A number of recent studies (Black & Widerhold, 2014; Bloom, 2014; Dimock, 2010; Koenig, Wingard, Sabee, Olsher, & Vandergriff, 2014; Tracy & Craig, 2010) have extended the utility of the core grounded practical theory assumptions. First, Koenig et al. (2014) examined doctor-patient exchanges when discussing Type 2 diabetes and a critical switch between oral medical to insulin injection. The authors randomly selected 55 patient visits from a total set of 400 audio-recorded interactions and followed conversational analysis (CA) methodology (Drew, Chatwin, & Collins, 2001; Robinson, 2011) to analyze their data set. Specifically, the authors found that "patients unproblematically accepted changes in medication they were already taking, including oral medication and insulin. However, patients often resisted changes in medication when it required treatment intensification, especially when the recommended change was from oral medication to insulin" (p. 251).

Koening and colleagues found "interactional sensitivity" as the philosophical rationale for their chosen techniques and also highlighted that interactional problems were not stable over time but rather shifted across the trajectory of the illness. Interactional sensitivity involved doctors being strategic in the use of their communicative strategies, such as, exchanging information, discussing options, and negotiating decisions according to clinical and social circumstances" (p. 262). That is, interactional sensitivity involved doctors strategically determining when, how, and what type of communication was warranted based on patient's individual circumstances. Ultimately, the study highlighted the different discursive techniques doctors enacted during these critical moments.

Bloom (2014) also applied GPT principles within a healthcare context but within a multilingual, transnational healthcare initiative in a Spanish-speaking country. Healthcare professionals involved individuals who were primarily English-speaking, some who were bilingual, and others who had limited Spanish-speaking skills. The Spanish-speaking country involved individuals who were primarily Spanish-speaking with limited English-speaking skills and others who were bilingual. Healthcare professionals were tasked with assessing medical needs and provide them with the best care possible.

The problem Bloom uncovered was that healthcare professionals' found a need to balance efficiency in transferring medical information in patient exchanges with the need to build rapport with the patients. Bloom found that all stakeholders developed hybrid translation strategies to overcome the interactional problem. According to her findings, "both cross-language (English–Spanish) and multidialectical (Spanish–Spanish) interpretation, these participants developed a hybrid approach for challenges of layered linguistic difference… negotiating back and forth with terminology, gestures, and dialects, the participants and patients developed a mutual understanding through translingual strategies for communicating…" (p. 280). Bloom showed that these healthcare professionals developed hybrid translation strategies to overcome the interactional problems and suggested the "negotiating language" served as the underlying normative model.

Koening and colleagues and Bloom both highlighted how GPT can uncover complex and multifaceted problems across social systems (e.g., healthcare). However, they positioned communicative problems as matters of "balancing" between two opposites. Although the foundation of dilemmas involve contradictory goals. In the current study, I show how GPT can not only identify contrasting and dilemmatic goals, but also how strategies can show how stakeholders can go beyond "balancing" conflicting goals and move toward more transcendent, integrative, and inclusive strategies for addressing problems in/by professional formation.

The current study extends grounded practical theory in an important and fundamental way. As shown, typical grounded practical theory studies focus on the everyday instances of "talk" highlighting how participants reveal the underlying, philosophical rationale for their communicative choices. Studies guided by a ground practical theory methodology mostly focus on a particular communicative setting, format, or interaction (e.g., doctor-patient exchange, multilingual interactions). A grounded practical theory framework points to the goals, problems, and communicative strategies participants display within those settings. The present study applies the principles of grounded practical theory to broader constitutive and generative organizational processes – in this case, processes of professional formation. Doing so broadens the aperture of GPT principles, deepening the theoretical framework's epistemological and ontological contributions while also extending its utility as a normative, pragmatic mode of organizational communication inquiry above and beyond micro instances of "talk".

The current study's contributions are analogous to Leonardi's (2010) work on the automotive engineering industry. The current project's findings similar to Leonardi revealed a discourse of determinism. Leonardi examined the evolution of car crash testing and debunked the narrative of a rational, linear progression from road testing to lab testing to mathematical simulation models. In other words, his work presented a co-evolution of several factors leading toward mathematical simulations rather than as an "exclusive result of technological innovation" (p. 268). Deterministic talk in general, as Leonardi (2008) described, "provide cognitive relief about an uncertain future" (p. 979).

He argued that a discourse of technological determinism obfuscated how car crash testing ultimately led to the use of mathematical models. Leonardi's work showed a co-evolution of various factors influencing the prevalence of mathematical simulations—factors, such as, regulatory, technological, and organizational structure changes. Technology changes influenced stricter regulations on how the industry went about testing which impacted how auto organizations were structured in response to and advance of these changes. Technology innovations provided more sophisticated ways for car testing (i.e., mathematical simulations), which motivated stronger industry regulations and use of new technologies, while organizations were creating new organizational roles and responsibilities in response to and advance of these environmental changes. Therefore, the use of technology was in fact a co-evolution of various factors.

Leonardi's work maintains several parallels to the current study. In my analysis, I found a discourse of 'professional determinism' where many stakeholders described success in the professional marketplace as determined by specialization and mastery of a niche area of biomedical engineering (e.g., molecular biology, implantable devices, biomechanical design). Similar to Leonardi, this sort of deterministic talk provided many stakeholders 'cognitive relief about an uncertain future'—in case of the current study, the uncertainty of entering and surviving in the professional marketplace.

Underlying deterministic discourses exist problematics of professional preparation and matters of inclusion. That is, deterministic talk limits the possibilities for how professional practice can be enacted, valued, and expanded, closing off space for diverse ways of valuing, thinking, and doing of professional engineering. As Leonardi (2008) discussed, a deterministic discourse "orders and naturalizes the world in a way that either explicitly or inadvertently promotes" (p. 980) interests of particular groups. Promoting interests of a group or groups of individuals above and beyond those of others clearly presents issues of inclusion.

This study went further and built on studies of deterministic talk (Leonardi, 2008, 2010) and unpacked how and which communication designs or formats (i.e., lecture curriculum, undergraduate research, lab participation) maintained, supported, reproduced, or resisted deterministic discourses. Doing so, highlighted formats and strategies amenable to change and design and those that may lead to integrative and transcendent thinking, doing, practicing, and valuing of diverse professional formation processes. These strategies and their underlying philosophical rationale serve as launching pad for the intentional design of professional formation.

This section described design rationality and differences between technology-centered and human-centered design. I especially highlighted Krippendorf's (2016) contributions to the communicative implications of design and Cross' (2006) work illuminating the epistemological insight afforded in/by design. I unpacked the central assumptions of CaD and main elements of GPT. Given these theoretical concepts, I turn to the research questions the guide the present study.

Summary of research questions

The following section summarizes the central concerns of the current study and the research questions that guide this project. The first three research questions guide the empirical analysis portion of the study, whereas, the fourth and final research question focuses on a design stance toward the communicative analysis of professional formation.

Discourse(s) "are organized ways of talking, writing, and acting accordingly…discourses reside in communities of people who collaborate in enacting what constitutes their community…organizes their actions, and construct(s) the worlds they see" (Krippendorf, 2006, p. 11). Professional communities, conceptualized as discourse communities, maintain recurrent discursive practices, specific professional vocabularies, discourse-specific realities, and legitimized ways of conceptualizing the world (Cooren, 2015; Krippendorf, 2006). These discursive practices maintain tensions, contradictions, and problematics as individuals design their communication in attempt to resolve communization puzzles (Aakhus, 2007; Jacobs, 1994). Investigating how professional formation is discursively constituted reveals interactional and communicative dilemmas – problems that require design. Thus, this study's first research question is:

RQ1: What are discursive practices of professional formation within a school of biomedical engineering?

Similar to Jackson's (1998, 2002) normatively-pragmatic design methodology, RQ1 guides the "empirical examination of discourse practices".

Grounded practical theory (GPT) (Craig & Tracy, 1995) includes the normative concerns of design, the practical orientation of communication theory, and the utility of applied research programs. GPT provides the conceptual and methodological framework for surfacing the normative assumptions that guide how individuals make sense of and resolve interactional dilemmas related to the professional formation of engineers. That is, GPT uncovers the often times contradictory, normative ideals within interactional dilemmas. Reconstructing interactional dilemmas related to professional formation reveals normative ideals and thus produces idealized values, goals, and expectations of what professional engineering *should* look like. Thus, the second research question for the current study includes:

RQ2: How does Grounded Practical Theory (GPT) identify conflicting goals in professional formation, strategies for overcoming conflicts, and the underlying rationale for strategies?

Professions, as discourse communities, are brought into life in and by discursive practices (Cooren, 2015). It is important, therefore, to understand interactivity as a constitutive premise in the professional formation of engineers. That is, understanding what interactivity presupposes about communication (Aakhus, 2007) reveals how formats of interactions creates and maintains a discourse of the engineering profession. Interactivity is a design tool for the communicative constitution of the professional formation of engineers (Aakhus, 2007). Therefore, this study's third research includes:

RQ3: How can Communication as Design (CaD) suggest what communication designs presuppose about what it means to be a professional engineer?

The first three research questions: (a) show how the engineering profession is discursively maintained, (b) highlight the tensions, contradictions, and problematics found in interaction formats, and (c) draw attention to interaction formats and what they presuppose about professional formation. Insights garnered in/by both GPT and CaD frameworks provide normatively, pragmatic assumptions school administrators can use as design criteria for building stronger formats of professional formation. Specifically, CaD highlights how interactivity and designs of communications shape and are shaped by epistemological and ontological understandings of what it means to be an engineer.

Human-centered design (HCD), elucidating the multiple human experiences of immediate stakeholders, acknowledges and brings forth the need to identify and (re)construct the social worlds in the process of design (Krippendorf, 2006). In other words, a human-centered design enterprise asks, what are the many social and material worlds present in a specific community? And how are these worlds communicatively constructed and maintained*?* The response to these questions generates an understanding of the current conditions of some problem space as well as some other desired end. Responses to these questions also ground this study's design stance of professional formation. The design stance of this study illuminates the processes by which members of biomedical engineering communities strive to realize preferred professional ontologies and epistemologies. The human-centricity involved in intentionally (re)designing individuals' discursive environments provides implications for and suggests a different view of "humanness" in human-centered design. The research question includes:

RQ4: How can principles of Human-Centered Design (HCD) contextualize a design stance of professional formation?

RQ4 reveals the creative activity of designers (Aakhus, 2007)—the design knowledge created in the process of realizing some desired end, and ultimately leading to and optimizing communication designs of professional formation. HCD offers and provides an additional design layer to the current project. HCD principles complement the conceptual and methodological elements of GPT and CaD and provide reflective frames from which to engage and consider how social worlds are impacted in/by design as well as the centrality of communicative practices.

In the next chapter I lay out the methods I implemented to answer these four research questions. The methods chapter discusses the participants, data gathering procedures, and data analysis process I implemented to produce this study's findings.

CHAPTER 3: METHODOLOGY

This study took an empirical examination of the discursive practices of engineering. Doing so revealed how engineering, within the study context, was discursively constructed and maintained. Understanding a discourse of engineering revealed inconsistences, tensions, and contradictions that lead to problematic, interactional dilemmas in the professional formation of engineers. Based on insights gained from the discursive practices, I identified interaction formats that contributed to problematic aspects for professional engineering formation. In this chapter I begin with the (a) participants involved in this study. I then turn to the (b) data gathering procedures, laying out how I used semi-structured interviews for data collection procedures, and then conclude with (c) my data analysis procedures which included a grounded practical theory approach (Craig & Tracy, 1995) following a constant comparison method (Lindlof & Taylor, 2011; Maykut & Morehouse, 2001).

Participants

Participants for this study included undergraduate students, faculty, staff, and administration (FSA) at a school of biomedical engineering (BME) at a large Midwestern University. Table 3 provides a list of pseudonyms for all of the study's participants. Given that engineering students at Purdue are not formally admitted into their respective schools until their sophomore year, undergraduate students from sophomore to senior year were included in the study. According to the university's public reporting (University, 2017), as of 2016, there were 278 undergraduate BME students and a total of 87 faculty and staff (including both full and part-time positions). The FSA total includes: 12 adjunct faculty; 19 clinical professors, research faculty, post doc, or visiting faculty; 35 staff members; and 21 tenured/tenure-track faculty.

Table 3: Participant table

Student Name	Major	Year	Faculty Name	Area	Tenure
Miguel Myers	BME	Junior	Brian Beemer	BME	Assist
Maggie Myers	BME	Senior	Bob Beemer	BME	Full
Marla Myers	BME	Sophomore	Brad Beemer	BME	Assist
Michelle Myers	BME	Sophomore	Brenda Beemer	BME	Assist
Melvin Myers	BME	Senior	Bruce Beemer	Dual	Full
Mickey Myers	BME	Senior	Blake Beemer	BME	Staff
Mitch Myers	BME	Sophomore	Brody Beemer	BME	Staff
Marley Myers	BME	Junior	Bernadette Beemer	BME	Assist
Marvin Myers	BME	Sophomore	Ben Beemer	Dual	Assoc
Marshall Myers	BME	Sophomore	Barry Beemer	BME	Assist
Maureen Myers	BME	Sophomore	Braxton Beemer	Dual	Assist
Melissa Myers	BME	Sophomore	Barnaby Beemer	Dual	Assoc
Mackenzie Myers	BME	Sophomore	Barron Beemer	BME	Assist
Macy Myers	BME	Sophomore	Bart Beemer	Dual	Full
Molly Myers	ABE	Senior	Brittany Beemer	BME	Staff
Melanie Myers	ABE	Sophomore			
Melora Myers	IE	Junior			
Max Myers	IE	Senior			

Students and FSA members are important for the current study given the impact both groups have in the professional formation of engineers. Both members exist in a mutual reciprocity in the professional formation of engineers given that professional formation cannot be accomplished without the other. BME engineering students represent individuals currently involved in the process of professional formation. Therefore, their perspective is critical in order to understand communicative and interactional dilemmas in the professional formation of engineers. Faculty, staff, and administration are also valuable stakeholders for this study. FSA members have a significant influence over how engineering students are developed into professionals. As authoritative figures, they maintain power over normative dimensions of professional formation—that is, what sorts of knowledge *should* BME engineers know? What *should* be valued in BME? What is taboo in BME? What processes (formal and informal) *should* lead to professional BME engineers? Given the importance of these groups "criterion sampling" (Lindlof & Taylor, 2011) was conducted. That is, participants for this study met the criteria of being either a BME student or a BME faculty, staff, or administration member.

Data gathering procedures

The data gathering procedures for this study included obtaining semi-structured interviews involving different groups of students and FSA members in each round. Interviews explored participant's descriptions, accounts, and experiences related to professional engineering formation (Lindlof & Taylor, 2011). Interviews also were used to identify problematic designs of professional formation or instances where students and FSA faced a communicative dilemma.

The protocol for this study's semi-structured interviews (see Appendix B) was constructed to uncover: participants' understandings of what it means to be a BME engineer, what knowledge is required in BME engineering; typical daily practices and activities in BME; professional activities required in BME; aspects of diversity and inclusion; relationships (e.g., student-student, student-faculty, faculty-faculty) in BME; and descriptions of the organizational culture at the school. Interview data was used to reveal discursive practices that produced and maintained a discourse of professional engineering addressing RQ1.

Participants were recruited from the larger NSF grant (award id: 1636446). Student participants, as part of the NSF study, completed an online questionnaire (n=200). I sampled student participants for this current study from those who completed the questionnaire. Participants were selected based on: demographic information as well as their responses to a select number of questionnaire items. This provided a diverse set of perspectives and experiences. Selection was also conducted to mitigate bias from one category of participants—that is, overrepresentation in categories, such as, gender, year in school, prior experience with engineering, and so on. Upon completion of the online survey, the last survey question prompted students to indicate interest in a follow up interview for which they would receive $15 dollars in cash for their participation. Direct email information was collected from those students who indicated they interest to participate in a follow up interview. I then emailed the students who indicated interest to participate in the interview via email and coordinated the date and time of the interview.

I received approval by Institutional Review Board to conduct the student and FSA interviews (see Appendix A). All participants were provided with consent forms notifying them of their rights as human subjects in this study. I conducted 33 total interviews, including 18 student interviews and 15 FSA interviews. FSA interviews included: 27% tenured BME faculty; 53% assistant professors; and 20% staff members. Both sets of interviews for students and for FSA were conducted during the Spring 2017 semester.

BME faculty, staff, and administration (FSA) individuals were invited to participate in the interview portion of this study via email. A complete roster of FSA contacts was acquired based on prior relationships with BME administration. The email informed individuals to email me directly if they were interested in participating in the study. FSA participants were not compensated for their participation in the study.

Data analysis

Data analysis primarily followed a grounded theoretical framework (Glaser & Straus, 1967). Following the constant-comparative method (Lindlof & Taylor, 2011; Maykut & Morehouse, 2001), I developed categories and coding schemes as they emerged from the qualitative data. This inductive process unpacked the various meanings produced by qualitative data, “as each new unit of meaning is selected for analysis, it is compared to all other units of meaning and subsequently grouped (categorized and coded) with similar units of meaning. If there are not similar units of meaning a new category is formed" (Maykut & Morehouse, 2001, p. 134). I used the constant-comparative approach in combination with the core principles of grounded practical theory (Craig & Tracy, 1995)—goals, strategies, and ideals. I discuss below in detail how I uncovered these core GPT principles following the constant-comparative methods.

A constant-comparative approach allowed me to draw connections from qualitative data to discourse-specific concepts, such as, recurrent discursive practices, common vocabularies, and forms of legitimization. This approach revealed how participants used discursive practices to construct and maintain engineering as a profession; what dilemmas emerged in and by these discursive practices; and what professional formation design presupposed about communication and by consequence the communicative constitution of the engineering profession.

I allowed concepts, topics, and themes to emerge from the data rather than imposing concepts from predetermined theory (i.e., deductive process) (Lindlof & Taylor, 2011). I "chunked" data based on textual units, such as, common terminology, phrasing, and vocabulary. The meaning of these "chunks" lead to conceptual categories. As Lindlof and Taylor state, categories are "an array of general phenomena: concepts, constructs, themes, and other types of 'bins' in which to put items that are similar" (p. 246). Codes were then developed to refine the categories that emerged from the data. Codes were created to "label, separate, compile, and organize data" (p. 248).

The initial categories for this analysis started with the six cultural dimensions of engineering education introduced by Godfrey and Parker (2010) (see Table 3). The dimensions served as a comprehensive starting point for unpacking the intersection of engineering identity, knowledge, and culture.

Table 4: Godfrey and Parker's (2010) Cultural Dimensions of Engineering Education

Cultural Dimensions	Cultural Understandings
An Engineering Way of Thinking	*What kinds of knowledge are valued? What is perceived as truth? Is there a prevalent way of thinking? What constitutes reality?*
An Engineering Way of Doing	*How is teaching and learning accomplished – what do our practices tell us about our assumptions of the "right" way to teach/learn?*
Being an Engineer	*Are there attributes and qualities inherent in being "an engineer"? Who fits in and is successful?*
Acceptance of Difference	*How is difference accepted and valued?*
Relationships	*How do people relate to one another in this culture?*
Relationship to the Environment	*What is our relationship to the rest of the university and academia in general, the profession and the community?*

Adapted from: Godfrey, E., & Parker, L. (2010). Mapping the cultural landscape in engineering education. *Journal of Engineering Education*, *99*(1), 5–22.

The interview protocol was partitioned by Godfrey and Parker's cultural dimensions and I first coded interview transcripts by the section of the interview protocol. For instance, all questions and responses within the section of the interview protocol related to the culture of the school were categorized (i.e., partitioned) as "Disciplinary culture". All questions and responses within the section of the protocol related to *what it means to be an engineer* (i.e., ontology) were categorized as "What it means to be an engineer". This process was repeated for all the main sections of the protocol. This process served as the initial phase of distilling and synthesizing this study's interview data. Godfrey and Parker (2010) is a foundational piece in the study of engineering education culture and therefore serves as a critical framework for studying the professional formation of engineers.

I then proceeded to inductively unpack the various meanings produced in and by these various cultural categories. I began grouping each text phrase into conceptually similar clusters given the meanings represented in/by each phrase of interview text. Specifically, I applied the GPT framework to develop and refine additional categories and codes focusing on goals, strategies, and ideals.

Craig and Tracy (1995) suggest the starting point of a GPT analysis begins by identifying a problem or dilemma facing individuals as they communicate. GPT is built on the assumption that "communication problems typically arise because communicators pursue multiple, competing goals or purposes such that conflicts among goals often emerge to block ongoing discourse…" (Craig & Tracy, 1995, p. 254). The problem level of analysis involved addressing questions such as, "What are the problems actors face as they seek to communicate appropriately? What concerns do actors themselves have?" (p. 255). Thus, goals are important to identify and unpack in order to provide a comprehensive problem level analysis.

Specifically, as part of this problem level analysis I focused on expressed and implied goals of professional formation. I searched for statements of praise to unpack participants' goals in/by professional formation. Praise statements included phrases, such as, "I think the lab setting is *definitely really* important." Additionally, I examined specific references to goals, aims, and expectations of their professional formation experiences. Similarly, I searched for statements of criticism to identify instances when goals were in conflict with one another. Criticism statements included phrases like, "The *hard part* about BME is that it is so broad, and that's a *criticism*." Criticism statements also reinforced goals by surfacing needs that participants felt were being unmet. For instance, a criticism such as "…CAD modeling is something where BME *doesn't* teach you" implied a goal of receiving specific technical training. By unpacking goals and conflicts, I was able to provided a multifaceted and contextualized problem-level analysis. Focusing on the problem also revealed dilemmas that maintained competing goals, interests, experiences, and so on.

I grouped each student and FSA interview transcript into similar praise and criticism statements. This process resulted in 14 pages of single spaced text praises statements and 7 pages of single spaced text of criticism statements. I then organized this data based on textual units, such as, common terminology, phrasing, and vocabulary (Lindlof & Taylor, 2011) focusing on engineering identity and knowledge—key concepts of professional formation. This process resulted in 12 identity codes and 11 knowledge codes. An example of one of identity code statements (for both FSA and students) included, "BMEs directly improve people's lives." An example of a knowledge code included, "BMEs should know how to synergize disciplines." I continued to iterate and refine each category and code until I could no longer move any code into a new or distinct category. My analysis resulted in two conflicting goals of professional formation: *gaining a broad knowledge base* and *realizing specific application*. The analysis process also revealed three distinct themes that layered the problem in/by these conflicting goals. The three themes included: *learning everything and not learning anything, inhibiting opportunities for developing specific skills,* and *developing a jack-of-all-trades identity*.

The second level of analysis in GPT (i.e., the technical level) involved the "specific communicative strategies and techniques that are routinely available to be employed within the practice" (Craig & Tracy, 1995, p. 253). This type of analysis involved practices individuals enacted as they managed communicative problems. At this level of analysis, I isolated the problems, conflicts, and goals that were identified during the problem level analysis and searched for articulated or implied strategies that enabled participants to either overcome conflicts or reach their desired goals. For instance, one problem that surfaced in my analysis was a lack of opportunities for developing specific technical skills (e.g., training in CAD modeling). Participants shared that in order to overcome the lack of opportunities and realize their goal of specific training, they relied on communication designs such as undergraduate research or their laboratory coursework. Undergraduate research and laboratory curriculum were strategies that participants enacted to overcome conflicts and reach professional formation goals. As each strategy was identified I followed my constant-comparative analytic approach and organized each strategy into categories until three distinct theme codes emerged: undergraduate research, laboratory curriculum, and the school's physiology course.

The third and final level of analysis involved highlighting the normative ideals individuals oriented to as the rationale for their strategies. Normative ideals were uncovered and inferred from interview data where participants described current and past talk instances of the problems in/by professional formation and the strategies they used to overcome these problems. Specifically, I unpacked each strategy and looked for similarities and overlapping concepts. At this level of analysis I focused on why the identified strategies were chosen above and beyond others. For instance, I looked for statements such as, "I really liked labs *because* I was able to see how things work." I also examined what the distinctive features of these strategies said about the underlying rationale. For example, "labs were helpful *because* I was *able to play around* with different ideas". In this last example, the context afforded by the lab strategy was an important and distinctive feature for why the participant chose this particular strategy. I followed the same constant-comparative method described above. Throughout this process, the categories and themes that emerged resembled the core dimensions of situated learning theory (Lave, 1988; Lave & Wenger, 1990; Brown et al., 1989; Stein, 1998), including: content, context, community, and participation. At this level of analysis, I was able to unpack the “why” behind participants’ strategies.

In this chapter I described the methods I implemented in this study including (a) descriptions of the participants, (b) data gathering procedures for semi-structured interviews, and (c) the GPT framework used for data analysis. These methods yielded key findings that answered my four research questions. In the next chapter I discuss these findings and lay out how grounded practical theory provided a framework that uncovered problems in professional formation, strategies participants used to overcome these challenges, and the underlying rationale for these strategies. Additionally, and given this study’s design stance on this empirical analysis, I highlight where CaD and HCD principles complemented and further augmented these findings.

CHAPTER 4: FINDINGS

This study's analysis revealed a situated dilemma in the interactive and constitutive processes of becoming a biomedical engineer (BME). Participants explained that gaining a broad knowledge base, spanning many engineering and science disciplines was needed to become a biomedical engineer. Participants revealed that realizing the specific application and technical know-how of their work was also a goal of becoming a biomedical engineer. The theme of specific application in the context of the present study was defined as developing specific skills, (a) to learn how to apply the broad knowledge base required in BME, (b) to produce a desired outcome and provide impact, and (c) to be competitive in the professional marketplace. Findings suggested that participants felt that gaining a broad knowledge base often times came at the cost of realizing specific applications, which recursively created the situated dilemma in the process of becoming a biomedical engineer.

I begin the following chapter with (a) an overview of the study's research questions. I then turn to the core elements of the GPT framework: the problem level, the technical level, and the philosophical level. The (b) problem levels presents three themes including: *learning everything and not learning anything, inhibiting opportunities for developing specific skills*, and *developing a jack-of-all-trades identity*. I also discuss the two primary goals of professional formation revealed in my analysis: *gaining a broad knowledge base* and *realizing specific application*. Next, I discuss the (c) technical strategies used to overcome problems in professional formation. These strategies included: *contextualizing BME information and developing skills in/by research participation, cultivating content-specific knowledge through ownership*, and *"emphasizing the engineer" in a physiology lecture*. The (d) philosophical rationale is then presented including, *situated learning as a part of the professional formation process*.

Overview of research questions

In my analysis, I show how participants drew upon a variety of learning activities (i.e., undergraduate research, lab participation, and a physiology undergraduate course) to engage in integrative and transcendent thinking, doing, practicing, and valuing of both a broad knowledge base *and* realizing specific application of their work (Putnam & Powers, 2016; Putnam, Fairhurst, & Banghart, 2016). Individually, and in combination, these learning activities created space for more inclusive ways of being and practicing biomedical engineering—transcending problematic balancing and deterministic discourses. Participants' articulations resembled situated learning models (Lave, 1988; Lave & Wenger, 1990; Brown et al., 1989; Stein, 1998) insofar as they provide a consistent philosophical rationale for the strategies they used to overcome challenges in professional formation.

To organize this section, the first three research questions guided the empirical analysis portion of the study, whereas, the fourth and final research question served to augment the design stance toward the communicative analysis of professional formation. The first research question asked:

> **RQ1:** What are discursive practices of professional formation within a school of biomedical engineering?

This research question helped guide and uncover discursive practices that maintained tensions, contradictions, and problematics in processes of professional formation. A discursive approach also unpacked how the ontological and epistemological foundations were sustained and reproduced by structural designs (i.e., curriculum designs) as well as by the everyday interactions of stakeholders.

GPT provided the conceptual and methodological framework for surfacing the normative assumptions that guided how individuals made sense of and resolved the problems they faced in the professional formation of engineers. That is, GPT uncovered the often times conflicting, goals of professional formation and the underlying rationale that guided strategies for overcoming these conflicts. Thus, the second research question for the current study included:

RQ2: How does Grounded Practical Theory (GPT) identify conflicting goals in professional formation, strategies for overcoming conflicts, and the underlying rationale for strategies?

Professions, as discourse communities, are brought into life in and by discursive practices (Cooren, 2015). It is important, therefore, to understand interactivity as a constitutive premise in the professional formation of engineers. That is, understanding what interactivity presupposes about communication (Aakhus, 2007) revealed how formats of interactions created and maintained a discourse of the engineering profession. Interactivity is a design tool for the communicative constitution of the professional formation of engineers (Aakhus, 2007). Therefore, this study's third research includes:

RQ3: How can Communication as Design (CaD) suggest what communication designs presuppose about what it means to be a professional engineer?

The first three research questions: showed (a) how the engineering profession is discursively maintained, (b) highlighted the tensions, contradictions, and problematics found in interaction formats, and (c) drew attention to interaction formats and what they presupposed about professional formation. Insights garnered in/by both GPT and CaD frameworks provided normatively, pragmatic assumptions school administrators could use as design criteria for building stronger formats of professional formation. Specifically, CaD highlighted how interactivity and designs of communications shaped and were shaped by epistemological and ontological understandings of what it means to be an engineer.

The final research question provided an additional design layer that augmented the design stance taken in this study. The fourth research question asked:

RQ4: How can principles of Human-Centered Design (HCD) contextualize a design stance of professional formation?

Human-centered design (HCD), elucidating the multiple human experiences of immediate stakeholders, acknowledges and brings forth the need to identify and (re)construct the social worlds in the process of design (Krippendorf, 2006). In other words, a human-centered design enterprise asks, what are the many social and material worlds present in a specific community? And how are these worlds communicatively constructed and maintained*?* The response to these questions generates an understanding of the current conditions of some problem space as well as some other desired end. The design stance of this study illuminated the processes by which members of biomedical engineering communities strived to realize preferred professional ontologies and epistemologies.

RQ4 revealed the creative activity of designers (Aakhus, 2007)—the design knowledge created in the process of realizing some desired end, ultimately leading to and optimizing communication designs of professional formation. HCD offers and provides an additional design layer to the current project. HCD principles complement the conceptual and methodological elements of GPT and CaD and provide reflective frames from which to engage and consider how social worlds are impacted in/by design as well as the centrality of communicative practices.

“Balancing”, determinism, and discourse

The findings produced by the GPT analysis shows how participants discursively maintained a need to “balance” the goal of building a broad knowledge base with the goal of realizing specific application. In discussing this tension between breadth and depth, participants also explained how the lecture portions of the school’s curriculum – rooted more so in retention of information versus the application—especially influenced this tension. Although, participants did not specifically articulate the balancing metaphor (Lewis, Gambles, & Rapoport, 2007; Putnam, Phillips, & Chapman, 1996; Thompson & Bunderson, 2001), it was indirectly implied and introduced unrealistic and problematic organizational realities for what it meant to become a biomedical engineer. That is, the unrealistic expectation that gaining a broad knowledge base *must* come at the cost of realizing specific applications of the discipline, and vice versa. Before I discuss this study’s specific GPT findings it is important to briefly touch on the constraints of balancing metaphors and deterministic talk generally.

Work-life balance (WLB) studies (Grzywacz & Carlson, 2007; McMillan, Morris, & Atchley, 2010; Shaffer, Joplin, & Hsu, 2011) have unpacked the problematics of the balancing metaphor. WLB research suggests that the balancing discourse points to a singular version of organizational reality that tends to oversimplify the complexities of organizational life—in terms of WLB, the complexities of work. By doing so, the balancing metaphor limits the possibilities for truly transcendent and integrative solutions (Lewis, Gambles, & Rapoport, 2007) and obfuscates the nuanced, multifaceted challenges that exist in organizational life. In terms of the current study, findings show how formats of communication (e.g., lecture-based curriculum formats) influenced how professional formation was discursively maintained. I suggest that an over-reliance or over-emphasis of lecture-based curriculum cultivated a “balancing” discourse that forced individuals to value gaining a broad knowledge base at the cost of specific application.

A balancing discourse in the professional formation of engineers presented several ontological, epistemological, and ethical implications. For instance, given the prominence and format of a lecture-based curriculum, breadth of knowledge was maintained as an ontological and epistemological value above and beyond specific application. That is, lecture curriculum discursively maintained the notion that being a biomedical engineer meant being mostly a big picture thinker requiring knowledge in several, related pockets of expertise. Traditional lecture curriculum design also presented diversity and inclusion implications to the extent that these ontological and epistemological values (e.g., big picture thinker) appealed to certain groups and served as barriers for others to find a place within the discipline. A balancing discourse draws many parallels to deterministic talk – that is, "I *must* choose to either build a broad knowledge base *or* find ways to realize specific application."

Leonardi's (2008, 2010) work adds further nuance to the problematics of balance or deterministic talk. In my analysis, I found a discourse of 'professional determinism' where many stakeholders described success in the professional marketplace as determined by specialization and mastery of a niche area of biomedical engineering (e.g., molecular biology, implantable devices, biomechanical design). Similar to Leonardi, this sort of deterministic talk provided many stakeholders 'cognitive relief about an uncertain future'. In case of the current study, the uncertainty of entering and surviving in the professional marketplace.

Underlying deterministic discourses exist problematics of professional preparation and matters of inclusion. That is, deterministic talk limits the possibilities for how professional practice can be enacted, valued, and expanded, closing off space for diverse ways of valuing, thinking, and doing of professional engineering. As Leonardi (2008) discussed, a deterministic discourse "orders and naturalizes the world in a way that either explicitly or inadvertently promotes" (p. 980) interests of particular groups. Promoting interests of a group or groups of individuals above and beyond those of others clearly presents issues of inclusion.

The current study builds on studies of deterministic talk (Leonardi, 2008, 2010) and unpacked how and which communication designs or formats (i.e., lecture curriculum, undergraduate research, lab participation) maintained, supported, reproduced, or resisted deterministic discourses. Doing so, highlighted formats amenable to change and those open to integrative and transcendent thinking, doing, practicing, and valuing of diverse professional formation processes.

From a discursive point of view noted in Chapter One, discourse(s) is defined as "organized ways of talking, writing, and acting accordingly…discourses reside in communities of people who collaborate in enacting what constitutes their community…organizes their actions, and construct(s) the worlds they see" (Krippendorf, 2006, p. 11). I bring these definitions and points forward to draw out my results and implications. Specifically, my results pointed to how formats of professional formation (i.e., standard lecture curricula, undergrad research, design experiences) presupposed something about how biomedical engineering ontology and epistemology were discursively constructed and maintained.

Discourse, constituted in language and communication, is open to new vocabularies and ways of talking and acting. Individuals can intentionally change and encourage new practices, new vocabularies, new descriptions, new conversations—ultimately, "new ways of conceptualizing the world" (Krippendorf, 2006, p. 12). Therefore, dilemmas are a good entrée point to explore how individuals introduce new ways of what constitutes their community.

Dilemmas force individuals to find new ways to overcome, engage with, or otherwise live with or in tension. The strategies individuals choose to enact challenges the status quo and reveals how individuals redesign the discourse of their communities and highlights opportunities for supporting ongoing redesign. This analysis explored and highlighted how members of the biomedical engineering discourse community encouraged and invested in strategies that introduced new ways of conceptualizing their professional world.

Given this study's grounded practical theory (GPT) framework (Craig & Tracy, 1995), the following analysis begins at the problem level and discusses how the school's lecture and active learning curriculum influenced how participants talked about and acted towards the professional formation of biomedical engineers. The technical level follows, highlighting the various learning activities and strategies participants used to generate integrative and transcendent thinking, doing, practicing, and valuing of both a broad knowledge base *and* specific application. The analysis concludes with a textured view of how participants' articulations resembled situated learning (Lave, 1988; Lave & Wenger, 1990; Brown, Collins, & Duguid, 1989) principles providing a consistent philosophical rationale for the learning strategies they chose.

The problem: Balancing broad learning and specific application

In my analysis, I uncovered a critical dilemma in the professional formation of engineers. Participants found themselves needing to balance between broadly learning several areas related to BME (e.g., biology, anatomy, electrical and mechanical engineering) with specific ways for applying knowledge and generating tangible impact. This dilemma involved three interrelated problems of professional formation: *learning everything and not learning anything*, *inhibiting opportunities for developing specific skills*, and *developing a jack-of-all-trades identity*.

At the problem level, the lecture instruction portion of the school's curriculum influenced, across multiple and interrelated levels, how participants talked about, acted towards, and discursively maintained the professional formation of biomedical engineers. Specifically, traditional lecture curricula reinforced the problematic balancing metaphor of gaining a broad knowledge base against realizing specific applications. The discourse also involved positioning lecture instruction, framed as a primary resource for a broad knowledge base, against more active learning methods (e.g., design experiences, lab participation), a resource for realizing specific applications. This discursive positioning resulted in impossible solutions for any truly integrative and transcendent ways of becoming. The discourse resulted in *either* relying on lecture curriculum for breadth *or* active learning for depth, rather than curating all available learning formats into a strategically integrated and transcendent professional formation process.

Many students like Miguel discursively positioned active-learning formats, such as lab classes, against lectures.

> I guess I would say the lab classes are where we tend to learn a lot…I think you almost learn more in lab classes than you do in lectures, just because they're a lot more engaging and hands-on.

Lab classes in the biomedical engineering school, as the description denotes, are courses typically held in a laboratory setting where students are given the opportunity to apply the content and information presented in previous lecture formats. Lab classes represent a one-credit course requirement in contrast to the three credits for a typical lecture course. The lab classes are designed to also provide the opportunity for students to develop content-specific technical know-how and skills, above and beyond the theoretical knowledge gained in lecture. For instance, the school (BME website, 2019) describes a required biomechanics and biomaterials lab class as:

> Providing hands-on training in engineering and biological principles of biomaterials and biomechanics. Topics include evaluation and interpretation of experimental results, modeling and testing of tissue and body mechanics, and interactions of living (e.g., tissue/cell) and nonliving (e.g., biomaterial) systems.

The hands-on training in this course description included "evaluation and interpretation of experimental results" and involved, among other things, learning how to set up biological experiments, how to collect data to run statistical analyses using various statistical and programming packages, and how to apply interpretative frames to generate meaningful results. This lab course was primarily associated with a lecture focused on the biomechanics of hard and soft tissues. The school's website describes the lecture as covering:

> …the mechanics of biological materials, with applications in the musculo-skeletal system, nerves, spinal cord, and vascular tissue, down to the level of the cell. Topics include center of mass, moment of inertia, basic understanding of stresses, strains, and deformations, axial elements, pressure vessels, beams, torsion, viscoelasticity, and thermal stress.

The aforementioned lab class, therefore, required students to run specific modeling and experimental studies to explore the mechanics of biological materials such as the musculo-skeletal system, nerves, spinal cord, and so on. The desired takeaway of the lab is for students to not only gain specific technical skills (i.e., modeling, experimental study design) that can be applied in a variety of settings but also gain a deeper understanding of how topics discussed in lectures (i.e., mechanics of biological materials) occur in practice.

Miguel's comments not only distinguished lab classes against lectures as separate formation processes but also introduced normative assumptions of how learning occurs. Specifically, phrases such as, "the lab classes are where we tend to learn a lot" or "you almost learn *more* [emphasis added] in lab classes", highlight valuing of active learning formats above and beyond lecture formats. Similarly, Miguel shared that "they're [lab classes] are a lot more engaging and hands-on" revealing that practical knowledge gained in by lab classes was more valuable than theoretical knowledge gained from lecture formats. For Miguel, as for many other participants, meaningful learning could only involve a significant degree of engagement and more kinesthetic-related activities (i.e., hands-on). These value statements framed active learning formats as having greater importance than lectures and positioned practical or applied learning as a separate process in becoming, distinct from more theoretical-laden, lecture formats. This sort of discursive positioning and valuing of one professional formation process, over the other, limited any possibilities for integrating both breadth and depth into a streamlined process of becoming. The implication involved becoming a biomedical engineer that was not firmly rooted in the breadth of knowledge required by the field *and* the depth needed to succeed in the professional marketplace. In unpacking the findings, the results show how economics and marketplace expectations significantly influenced an orientation towards skills-building and a professional ontology rooted moreso in practice and application.

Miguel was a junior and was interested in moving towards a medical degree after undergraduate. He still relied heavily on the school curriculum as the main source of professional formation above beyond other formative experiences such as an internship or co-op positions. His reliance on the school's curriculum was evident in that he strictly addressed academic experiences as sources of learning (i.e., lab classes, lectures). In contrast to his more senior peers, Miguel was more likely to produce and maintain an "either/or" organizational reality where professional formation experiences (in this case) are either good or their bad given a lack of exposure to fluid organizational dynamics. His discursive maintenance produced and reproduced an ongoing valuing of active learning formats in opposition to lectures, rather than framing both as complementary and highly integrated in the professional formation process.

The role of lectures in higher education today has received increasing attention. Mazer and Hess's (2017) special issue on the place of lecture in student learning highlights some of the central arguments in the ongoing discussion. There are those, such as Meyer and Hunt (2017), who view lecture as a valuable instructional format for illustrating how to approach and work through complex problems. While others like Stearns (2017) take a strong stance against lectures altogether favoring instead active learning and student-centered approaches. Active learning and student-centered approaches, according to Stearns, allow students more responsibility in their learning and promote higher-order thinking and transfer of information to knowledge (Gavalcova, 2008; White et al., 2016).

There are, however, a number of scholars who view lecture and active learning as two poles of the same learning spectrum (Mallin, 2017; Waldeck & Weimer, 2017). From a spectrum stance the question then is not lecture versus active learning but rather how and when the two formats are and can be complementary. Waldeck and Weimer (2017) suggest "…teachers should make sound decisions based on the assumption that the deepest learning occurs when lecture and active learning are used strategically in relationship with another." For the current study, a spectrum stance creates space for counteracting against balancing and deterministic discourses that position lecture against active learning formats. Rather, I suggest that a spectrum view can introduce an "integrative" discourse whereby students and faculty alike can discursively position lectures and active learning as complementary parts of a cohesive process of becoming. From this perspective strategy and decision-making (Waldeck & Weimer, 2017) by all stakeholders are key for building an integrative discourse. Doing so not only assists in realizing learning outcomes but also contributes to the ontological and epistemological foundations of becoming a biomedical engineer.

In the current study, lectures, as a communication format (Aakhus, 2007), introduced core problematics in the discursive maintenance of becoming a biomedical engineer. For many participants, lectures introduced three interrelated problems in professional formation: *learning everything and not learning anything*, *inhibiting opportunities for developing specific skills*, and *developing a jack-of-all-trades identity*. These problems in/by lectures contributed to a broader balancing discourse whereby students, faced with these lecture problematics, were forced to "balance" lectures with more active learning methods rather than framing the undergraduate curriculum as an integrative process of becoming a biomedical engineer. In speaking about how lectures influenced the process of becoming, participants also revealed the discursive nuances of the situated dilemma between gaining a broad knowledge base while also realizing specific applications.

Learning everything and no defined career pathways.

First, lectures created a sense of what Melora, a former biomedical student, described as learning everything and not learning anything. Melora was a junior who transferred out of BME to Industrial Engineering (IE). She suggested that traditional lectures introduced such a high volume of information that students either missed key connection points between interrelated topics or viewed the content as "extraneous material". Lectures did not provide a strategic direction, for Melora, to make sense of the content or otherwise frame the content in any meaningful ways. She expanded on the problematic of the lecture-based curriculum:

> …it was like we were trying to learn everything about everything all the time and no one was learning anything about anything all of the time. It felt like overkill a lot…What it ends up being is just, you don't really understand them…IE classes are very tailored to that kind of stuff [industry]…A class on…like production systems…where we essentially learn the entire process of how you would select a location for a manufacturing facility to how you, day-to-day, would run it. It's very practical application.

Melora's statement mirrors several of lecture disadvantages presented in higher education literature. Cooper (1981) noted that lecture is particularly ineffective when large amounts of information are likely to become overwhelming or if student needs require deeper reflection of material

Melora invoked a devaluing of the breadth of theoretical knowledge promoted in/by the BME school, with comments such as "it [curriculum] felt like overkill a lot." She discursively maintained an expectation of professional formation involving a clearly delineated path from the curriculum to well-defined professional practice and application. Furthermore, Melora argued "IE classes are very tailored to that kind of stuff [industry]…" Based on her description, the IE curriculum—in contrast to BME—met her expectation of a clear path from content to how she would apply this knowledge in her professional life. For her, what *really* mattered was the "practical application" and IE was able to seamlessly connect the curriculum to the application.

For Melora, the industrial engineering curriculum provided more well-defined applications such as, "production systems" or "…the entire process of how you would select a location for a manufacturing facility to how you, day-to-day, would run it." Formation, constituted by undergraduate learning experiences, in more well-defined terms such as described by Melora also limited a balancing discourse from surfacing. In this case, there was no need to balance between breadth and depth and distinguish between the two in part because of the IE curriculum design. Lectures in IE were rooted in building on clearly defined professional identities and applications and as such, breadth and depth were seamlessly integrated into a path toward building these professional identities. In other words, the IE curriculum was designed to meet clearly defined expectations of what an industrial engineering professional identity represented (e.g., understanding the process of production systems).

Interestingly, industrial engineering and biomedical engineering at the university share many of the same disciplinary characteristics. Both disciplines are in fact defined by their breadth moreso than their specific area of application. For instance, the website (University IE site, 2018) for the school of industrial engineering, similar to biomedical engineering, contrasts their disciplinary identity against other engineering disciplines who "apply skills to very specific areas". The industrial engineering school's identity statement states:

> Industrial engineering is about choices. Other engineering disciplines apply skills to very specific areas. IE gives practitioners the opportunity to work in a variety of businesses. Industrial engineering offers the best of both worlds: *an education in both engineering and business* [emphasis added].
>
> Industrial engineering is about more than manufacturing–it also encompasses service industries, with many IEs employed in entertainment industries, shipping and logistics businesses, and healthcare organizations.
>
> *Industrial engineers are the only engineering professionals trained specifically to be productivity and quality improvement specialists* [emphasis added].

The IE school promoted their uniqueness by being "the best of both worlds: an education in both engineering and business." Similarly, the biomedical school discursively maintained a professional identity in being both of engineering and of the human body. Bernadette a junior faculty, for example, described BME identity as "the idea of applying engineering and design concepts to biological problems…human focused biological problems." Ironically, however, the IE school's statement simultaneously describes both their breadth and also the ways in which they specialize. The IE school is able to circumvent issues of balancing breadth and application by promoting the two areas (or professional identities) in which industrial engineers are uniquely trained and qualified, "to be productivity and quality improvement specialists" (University IE site, 2018). In other words, the IE school's identity claims are almost to say that in a vast sea of industrial engineering information and applications, the ultimate aim or identity target is to be productivity and/or quality improvement specialists. The industrial engineering school used these two identity anchors as the ultimate goal of becoming or professional formation. I argue that the IE school provided students with an identity framework to navigate the breadth of information presented in/by the curriculum. In other words, as an IE student, what does the information I am receiving mean in terms of becoming a productivity and/or quality improvement specialist?

I analyzed the BME school's website, searching for statements that served as well-articulated identity anchors similar to the IE school, and the closest example I found included, "What is a Biomedical Engineer? A Biomedical Engineer solves novel life science and healthcare problems using the practical application of science and math. Biomedical engineers make a global impact by improving the quality of healthcare" (University BME site, 2018). Similar to the IE school, the BME identity statement captures the breadth of the field—that is, "solves novel life science and healthcare problems using the practical application of science and math—however, in contrast to IE, it does not provide specific professional identity targets students can use as frames to process large amounts of information in the curriculum. Thinking of the biomedical engineering school, the question could be posed, what are the areas in which biomedical engineers are "uniquely trained and qualified?" And how is the school discursively promoting, maintaining, and supporting these identities? How can the BME school anchor lecture instruction in coherent professional identity targets?

Although the lecture curriculum in the biomedical school created a sense of learning everything and not learning anything, the discursive maintenance that occurred was multifaceted and revealed lecture's complicated role in becoming a biomedical engineer. Participants argued, in fact, that a benefit of biomedical engineering's lecture curricula was providing the broad range of factual and procedural knowledge that is required in biomedical engineering. However, participants' descriptions also suggested that lectures, in and by itself, left students without organizing mechanisms for discursively creating and maintaining a coherent professional identity (or identities). That is, the overwhelming volume of information required by the discipline served as a barrier for developing coherent professional identities. With an overwhelming amount of information it is difficult to create and discursively maintain a professional identity (or identities) that, recursively, could also serve as anchors to process, select, retain, and apply the amount of information involved in the discipline.

A biomedical engineering student explained how the lecture-based curriculum existed as both a benefit and challenge. Marley was a Junior in the school and described the complexity of a broadly based lecture curriculum:

> It's not bad that you're learning…if you don't need it you don't want to use it, and if you don't use it you'll forget it. It's sort of, why am I paying for that?...You learn a lot. It's not all bad, it's not all good because some of it's just extraneous. Some of it you'll forget but either way, learning it, being taught it is not bad in and of itself.

Marley suggested a cacophonous learning environment with large amounts of information and learning taking place. What she intimated was that without a clear strategy or identity-driven pathway, the volume of information is "just extraneous". Phrases like "if you don't *need* it you don't want to use it, and if you don't use it you'll forget it…" imply that the amount of information in the curriculum is not driven by any overarching goal or aim. The goal in this case would be professional identity targets that serve as sensemaking mechanisms for how to strategically guide professional formation. The discursive maintenance shown is that learning or professional formation is not in and by itself enough but rather learning should be strategically orchestrated around a well-defined goal of professional identity. Marley suggested and interpreted learning simply as a value in and by itself to did not meet her professional formation expectations.

Marley also discursively positioned professional formation in economical terms. Going back to a phrase I presented above, Marley stated, “if you don’t need it you don’t want to use it, and if you don’t use it you’ll forget it. It’s sort of, why am I *paying* for that?” This phrase revealed actual economic investments, in this case investments into his professional formation, that may not produce meaningful or expected returns, namely, developing and maintaining a professional identity that will provide value. From an economic or market perspective, learning or professional formation must be strategically aligned with a well-articulated end goal in order to produce demonstrable results in a biomedical engineers’ professional life. The economic discourse provided further nuance into the ontological implications of becoming a biomedical engineer. Will I become the professional biomedical engineer I sought out to be if I invest financially? Will I become the sort of professional biomedical engineer I sought out to be if I invest my time and effort? Do I even know what sort of professional biomedical engineer I should be after this investment?

Two key elements emerged at this point of my analysis. First, professional identity (or identities) was/were required to help wade through the volume of information presented in the biomedical school’s curriculum. In other words, what ontologies are being maintained by the curriculum and how do these ontologies help students navigate the substantial volume of information presented in the professional formation process? Building identity anchors in/by lecture instruction was particularly limited given that the lecture format did not create space for *how* the breadth of information contributed to becoming a biomedical engineer.

Second, developing, maintaining, and promoting biomedical ontologies, or identities, provided goals in which to strategically design available learning formats and experiences. In other words, well-grounded biomedical engineering ontologies could provide students and faculty pathways for how to strategically choose and implement lecture and active learning formats to build transcendent, integrative professional formation processes. Developing professional ontologies required formats that could support theoretical and abstract epistemologies while also delivering the procedural knowledge and specific "skills."

Inhibiting opportunities for developing specific skills.

The second problematic of lecture instruction involved many students feeling that lectures alone were a barrier for developing specific skills needed for their professional life. The lecture format was suitable for surveying and exposing students to the wide range of theoretical, procedural, and technical knowledge in biomedical engineering. However, given the shear scope of content, the lecture format in and by itself did not provide many opportunities for students to make sense of theoretical knowledge, participate in the application of this knowledge, understand what skills were needed in a particular situation, and how to develop these skills.

Mickey, a senior biomedical engineer undergraduate student, was a perfect example of how many students were left searching for ways to fill a perceived skills-development gap attributed mostly to lecture instruction. I spoke with Mickey during the Spring semester and he was in the midst of his post-undergraduate job search. The realities of the job market at the time of our interview were beginning to sink in and he was especially attuned to what being a biomedical engineer did and did not mean in the professional marketplace. His description of what biomedical engineers "do", discursively positioned the profession by the specific skills he felt were needed to enter and survive in the marketplace. Without well-articulated professional identities, “doing” biomedical engineering was at risk of being discursively defined solely by the technical skills that were expected in the marketplace rather than the integrative and holistic dimensions of the discipline. During my analysis, a strong theme that emerged were how powerful the influences of the marketplace were in constituting professional identities and ontology. That is, in many ways, what a biomedical engineer was or did was constituted by the economic realities of the marketplace (i.e., whatever will get me a job). For instance, Mickey shared what he believed biomedical engineers did by describing what he saw companies were looking for in new hires. He stated:

> It seems like it’s [job market] a lot of proficient in SolidWorks, proficient in C, or proficient in LabView. I feel like the BME program, it would be nice to be a little bit more proficient in some of those things than I currently am. I lucked out for high school, became pretty proficient in SolidWorks, but thinking if I hadn’t had that I feel like I would not be able to identify with some of those things…

As he made these comments, his frustration was evident. His tone was almost to say, *I just realized what a biomedical engineering degree can and can’t do and I might not have the assets to enter and succeed in the marketplace*. His frustration was also evident in phrases such as, “I feel like the BME program, it would be nice to be a little bit more proficient in some of those things than I currently am.” His comments were in direct reference to a perceived skills-gap in the overall pedagogical structure and something he felt was problematic for becoming the professional that he felt he needed to be to enter the job market.

Mickey’s ontological descriptions of biomedical engineering were articulated in strictly skills-based terms. He listed skills such as, “proficient in SolidWorks, proficient in C, or proficient in LabView” in his description of marketplace demands and connected these demands to what it meant to be a biomedical engineer. There was no mention of the job market requiring a broad theoretical knowledge base, or having some exposure to various engineering and science disciplines, or straddling both engineering and physiological sciences – outcomes of the traditional lecture curriculum. But rather, Mickey discursively defined what it meant to be a biomedical engineer by a skills-based, market expectation. Given this definition he realized that the current curriculum was not fulfilling this expectation and he was required to lean on other experiences (i.e., "I lucked out for high school, became pretty proficient in SolidWorks") in order to realize what he felt was needed to become a biomedical engineer.

Interestingly, Mickey, was fortunate to have gone to a high school with the resources to teach specific engineering skills such as designing in the computer aided software package, SolidWorks. There were several examples from other students where they described their high school experiences and the many opportunities they were given to learn technical skills similar to designing in Solid Works—opportunities they felt allowed them to overcome a perceived skills-gap in the curriculum. The discourse maintained by Mickey's comment, and several others similar to him, was that the marketplace demanded specific skills that were not currently being developed by the biomedical school's curriculum. And given this void, many students relied on the technical skills (i.e., designing in SolidWorks) they gained in high school or other experiences outside of the curriculum to meet the demands of the marketplace and their own expectations of what it meant to be a biomedical engineer.

This multifaceted dynamic between marketplace expectations, professional identities, and professional formation processes created apparent diversity and inclusion iniquities. Simply put, in order to navigate a perceived skills-gap, the current status quo required students to pull from privileges gained prior to entering the biomedical engineering program (i.e., high school engineering experiences). Students who were not afforded these same privileges began their professional formation experience at a significant disadvantage compared to their peers.

The suggestion of “tracks” or “specializations” was also often invoked as a remedy for a perceived lack of skills development attributed to the curriculum broadly and lectures specifically. The terms “tracks” or “specializations” were used often to describe focus areas where undergraduate students could build on a specific area of expertise by taking courses related to a specific focus—within the broader umbrella of biomedical engineering. For instance, one track could be a biomechanics specialization where the curriculum would include predominately mechanical engineering related courses, concepts and skills—all within the context of biological and human systems.

Another example of tracks can also be found at the university’s school of industrial engineering. The IE school offered specializations in areas, such as, human factors, manufacturing, operations research, and production systems (University IE site, 2018). For instance, the human factors specialization focused on “exploring cognition & decision making”, manufacturing on “next generation products & services”, operations research in “improving computational IE”, and production systems focused “on complex systems & networks” (University IE site, 2018). I argue that the IE specializations, although focusing on specific expertise and skillsets, are moreso constituted by a problem-focus than any specific skillset. This is important to note as I continue my analysis and unpack how the biomedical engineering can discursively maintain a professional identities that encompasses both breadth and depth.

Many participants believed that having tracks in biomedical engineering could have provided directed and targeted pathways for building a specified expertise and skillset. I argue that the desire for building specific expertise was rooted in an underlying need for developing coherent professional biomedical engineering ontologies. For instance, Marley expressed his frustration of what he implied was a perceived lack of strategy for developing expertise or a specified skillset in/by the curriculum.

> The problem is from my perspective there's not really a track…so no matter whether you want to go into tissue or bioelectricity or biomechanics, you're mainlined through your junior year. That's when you start to have a little bit more freedom, but by that time you spend a lot of time learning things that you never use again…instead of teaching me another circuits class, maybe I could have gone in ME and taken a dynamics class…that's more interesting and more relevant than another circuits class.

Marley revealed noteworthy discursive practices of how he positioned professional formation in/by the biomedical engineering school. First, he argued that the problem of his professional formation experience and inability to mount specified expertise or skills was that students were "mainlined through…junior year." His use of the word "mainlined" referred to the school's unique cohort model. The university required students interested in majoring in any of engineering discipline to first complete the First Year Engineering (FYE) program, typically during the student's freshman year. After students completed the FYE program they would then apply to register to a desired engineering major (e.g., mechanical engineering, electrical/computer engineering, biomedical engineering). If they met the school's admission criteria they were admitted and would begin their engineering major courses in their sophomore year.

The biomedical school, different from other engineering programs, followed a cohort model having each new incoming group of students take the same core BME courses each semester until their Junior year. BME students, for the most part, took the same BME sections to the extent that they would often travel in the same groups from class to class. The cohort model was unique compared to many of the other engineering schools. Students in other engineering programs did not require their students to take core courses at the same time, with the same group of students, but rather had more flexibility in when and how they designed semester course schedules. There were engineering programs such as computer engineering that did not provide much flexibility in terms of course selection and scheduling, but for the most part the biomedical engineering cohort was unique compared to other engineering programs.

Marley suggested that the cohort model and overall curriculum restricted him from building specific skills he sought in/by her professional formation experience. In addition to phrases such as "mainlined", he stated that after junior year students "start to have a little bit more freedom, but by that time you spend a lot of time learning things that you never use again." His use of "a little bit more freedom" suggested again that students were restricted to or subdued to an experience that they did not voluntarily view as worthwhile or fruitful for building a specified expertise or skills base. Marley positioned "tracks" against the cohort curriculum and as a way for building his professional identities, expertise, and skillsets.

Marley's desire for tracks also implied that there were certain areas of biomedical engineering knowledge that mattered and others that did not. These discursive practices suggested significant epistemological and ontological implications. Marley argued that students "spend a lot of time learning things that you never use again". His comments revealed that areas outside of his immediate focus were irrelevant or extraneous rather than framing these other areas of knowledge as integral or central to becoming a biomedical engineering. Similar to Mickey, Marley showed that without a coherent professional biomedical engineering identities, marketplace demands (i.e., expertise, skills needed to get a job) were predominately determining what it meant to be a biomedical engineering.

The biomedical engineering discipline, generally, and the school, specifically, face risks with the idea of tracks or specializations. For instance, if the school were to offer delineated tracks at the undergraduate level they risk becoming simply a variation of an already established engineering discipline (e.g., mechanical engineering, electrical engineering, chemical engineering) applied to a biological context. For instance, if the undergraduate curriculum provided a biomechanical track that included a predominately mechanical engineering curriculum, what would differentiate the biomechanical track from other mechanical engineering courses that focus in biological contexts? Simply put, students run the risk of becoming a mechanical engineer that works in biological contexts rather than a biomedical engineering with a particular skill set in mechanical engineering. The biomedical engineering disciplinary boundaries, as currently constituted, blur many engineering and science disciplines and therefore specializing in any one or more could further dilute any existing core biomedical engineering ontology.

I argue that, similar to the problematic of learning everything and learning nothing, a perceived skills-gap exposed a need for professional ontologies that provided students with a mechanism for processing information but also provided an aim for which to strategically curate all available learning experiences. Implications for the biomedical school included promoting and framing how the exposure of all biomedical engineering areas crystalized into particular problems or sets of problems (e.g., mobility).

The argument therefore may not necessarily be whether to build tracks or specializations but rather how to discursively construct coherent professional ontologies amenable to both the breadth of the discipline as well as to marketplace expectations. Using professional identities as guiding aims, students and faculty can build orchestrated and strategic paths toward becoming a biomedical engineer while also acknowledging specific marketplace demands in the co-creation of what it means to be a biomedical engineer.

A possible avenue to explore would be problem-centered organizing frames. Examples of problem-centered approaches can be found in many areas of research (Leavy, 2001; Peffers, Tuunanen, Rothenberger, & Chatterjee, 2014; Tracy, 2007) and pedagogy (Albanese & Mitchell, 1993; Colliver, 2000; Dunlap, 2005; Walker, Leary, Hmelo-Silver, & Ertmer, 2015). The idea of a problem-centered approach changes the focus from a purely skills-based orientation (i.e., mechanical engineering that builds mechanical engineering skills) to a holistic orientation—acknowledging all the disciplinary skills and expertise needed to approach a particular problem. An example can be found at the university study site. In celebrating their 150th anniversary the university launched a campus wide campaign to bring together various disciplines to address some of the word's largest problems. The problem-centered initiative focuses specifically on: health & longevity, sustainable economy & planet, artificial intelligence, and space exploration (University initiative, 2019). In terms of the biomedical engineering program, one possible approach could then be to offer students the opportunity to choose one or more of similar problem areas as the anchor for their undergraduate experience—for instance, health and longevity. Students would still be exposed to the breadth of information required by the discipline while also building skills through various learning experiences but would anchor all of these curated experiences within a community of practice and professional identities rooted in health and longevity.

Developing a jack-of-all-trades identity.

The third and final problematic found in/by lecture curriculum combined the risk of "learning everything" with a perceived skills gap. Together these problematics led to an overarching biomedical engineering identity discourse described as a "jack-of-all-trades". As a professional identity, the jack-of-all-trades description referred to the breadth of engineering and science disciplines represented in the biomedical engineering field. That is, being a jack-of-all-trades in the context of biomedical engineering meant having a basic understanding of many disciplines such as mechanical engineering, electrical engineering, biology, anatomy, and so on but not necessarily being an expert in one or more of these areas. The everyday use of the adage is often contrasted with the phrase "master of none", as in, "jack of all trades, master of none". Thus, the term implied that a jack-of-all-trades was someone who was well-versed in many areas but not a specialist or expert in any one particular area.

The discourse of being a jack-of-all-trades was widely held and entrenched throughout the school and expressed across most participants – students and FSA alike. For instance, Brian was a junior faculty member in the BME school and had been at the school for a couple of years at the time of the interview. He described the field's breadth and lack of strategizing as contributors to a jack-of-all-trades ontology:

> …you become so diffuse in your training that you've got a little bit of everything, and you haven't been able to specialize, and you didn't do research to really focus on an area, and if you can't really focus on it with an internship at a certain spot, there's a chance that you're going to interview with these companies at the end of your four years and realize, 'I don't have what they're looking for. They want somebody that's got more of a technical background or can contribute to one specific part, and I've got this big, broad training.' I think people need to strategize. Honestly, there are people in our department that worry about our BMEs that are coming out as an undergrad because it's so broad.

Being a jack-of-all-trades was a prominent dimension of the professional ontology that was produced, reproduced, and maintained within the biomedical engineering school. Importantly, stakeholders such as Brian were in a position of authority and able to influence the design of communication formats in professional formation. Faculty especially played significant roles in designing and building communication formats (i.e., learning formats) that supported a jack-of-all-trades identity. Faculty members, such as Brian, were aware of the dangers of the jack-of-all-trades identity, “Honestly, there are people in our department that worry about our BMEs that are coming out as an undergrad because it’s so broad”, however, were also in a position to redesign learning formats in a way that integrated the breadth of the field and practical experiences called upon in the marketplace.

Brian did begin a process of redesign, discursively, by suggesting “people need to strategize” and think of ways to embrace the breadth of the field while also building particular areas of expertise. Strategizing builds on Waldeck and Weimer’s (2017) position of how to navigate within a lecture <-> active learning continuum. In terms of professional formation processes, strategically designing and positioning various learning formats throughout a “becoming” lifespan can lead to highly integrative and transcendent ways of doing, practicing, and valuing both broad knowledge and specific application practice.

The specific challenges of lecture curricula, as a communication format, presupposed ontological and epistemological foundations of the biomedical engineering discipline as highly theoretical, technical, and dispersed across many disciplines. As a result, the professional formation process at the school discursively maintained a jack-of-all-trades ontology and limited transcendent ways of being a biomedical engineering.

In line with GPT studies such as, Koening et al. (2014) and Bloom (2014), current findings showed how situated dilemmas can block ongoing discourse. Koening and colleagues, in their study of diabetic patient-centered care, found that “while insulin may effectively help control an unstable disease, an insulin recommendation may simultaneously counter patient values and treatment preferences” (p. 244). The dilemma between effectively controlling the disease and recognizing patient’s treatment preferences blocked ongoing discourse of health communication, particularly in their instance, blocking a discourse of treatment intensification.

Similarly, Bloom found that hybrid translation strategies in transnational healthcare settings were needed to overcome the dilemma of balancing efficiency of information transfer and building interpersonal rapport with patients. The dilemma between information transfer and building rapport blocked an ongoing discourse of translingual healthcare communication.

The current study found that participants, during their professional formation experiences, encountered a dilemma of building a broad knowledge base while also attempting to realize the specific application of their work. The dilemma between a broad knowledge base and realizing specific application blocked an ongoing discourse of transcendent, integrative, and innovative professional formation. Additionally, and differently from Koening and Bloom, the present study (by integrating HCD and CaD principles) added another design layer to the GPT framework to expose and unpack how communication designs (e.g., lecture, undergraduate research, lab settings) sustained both the situated dilemma found in the current study as well as an overarching discourse of professional formation.

As I disentangled how participants' responded to these challenges, discursive themes reinforced the goals of becoming a biomedical engineer: gaining a broad knowledge base and realizing specific application. These goals were identified as participants described what it meant to be a biomedical engineer, what biomedical engineers should know, and how biomedical engineers were taught. Participants explained that gaining a broad knowledge base while also realizing specific applications was difficult to achieve during the professional formation process. While a broad knowledge base was achieved through standard lecture formats, they perceived that developing specific skills was often sacrificed given lecture's more often abstract or conceptual focus. The following sections describe the two goals of becoming a biomedical engineer in more detail.

Goal of professional formation—gaining a broad knowledge base.

Repeated discursive phrases included “broad knowledge”, “broaden impact”, “holistic understanding”, and “hard to define borders” when participants described biomedical engineering identity and what biomedical engineers should know. Biomedical engineering was defined as a collection of various science and engineering disciplines. As one faculty member put it, “everything that is engineering in the [human] body, for the [human] body, or the [human] body itself.” Participants explained that it was difficult to define the borders of biomedical engineering and “biomedical engineering-specific knowledge”. Rather biomedical engineering expertise was constituted in/by an amalgam of various disciplinary expertise.

The goal of or need for building a broad knowledge base required expansive and integrative professional formation processes that provided space for various content topics, situations, communities, and unique approaches to problem solving. That is, beyond specific content, the span of disciplines biomedical engineers are required to absorb included various values, beliefs, environmental cues, and communities that all interact to constitute the meanings of a situation, problem, and approaches for resolving.

Participants explained that biomedical engineers need a strong foundational understanding of the sciences typical of most engineering disciplines. Knowledge in the sciences included mathematics (with a particular emphasis on differential equations), modeling, and physics. The heavy emphasis of technology also required baseline knowledge of coding and computer science. In addition to math and technology, the human emphasis of BME required a broad understanding of biology, chemistry, physiology, and anatomy. Brian also described all the various elements that constituted BME knowledge. He stated that all BME engineers should know:

> Fundamentals of all basic engineering principles as much as they can. They don't have to know all the details of everything that a mechanical or electrical engineer will but you need to be able to talk their language…then also, how the human body works and from a biology standpoint, the underlying biology principles, fundamentals, terminology that go into medicine.

Brian's description highlighted the breadth involved in biomedical engineering and revealed the epistemological values discursively held in/by the discipline. Brian suggested that biomedical engineers do not need to be concerned in the details of every related discipline but at the very least "be able to talk their language". Discursively, he reproduced the discipline's epistemological breadth as a fundamental dimension of biomedical engineering professional ontology. That is, being able to speak other disciplines' languages was important knowledge (epistemology) for BME's to have and also a distinguishing characteristic of biomedical engineering identity (ontology). Noticeably absent in Brian's description was knowledge of application or of specific practice. Valuing only the discipline's epistemological breadth limited any opportunities for truly transcendent and integrative professional identities.

Brian also invoked discursively "synthesis" as an epistemological value in biomedical engineering. The ability to synthesize the breadth of disciplinary expertise was not only a knowledge claim but also an ontological value for biomedical engineers. Brian expanded on the relationship between breadth and synthesis:

> I think BMEs in general have a broad background. They have to understand a little bit of all the different traditional disciplines while synthesizing how all of them could be applied to the study of the human body.

Although Brian suggested how the breadth of the discipline could be applied through synthesis and study of the human body, in this particular comment, the anchor identity statement was "I think BMEs in general have a broad background". That is, Brian's comments on what biomedical engineers should know pivoted on the central ontology that BMEs have a broad background. A truly integrative and transcendent ontological and epistemological discourse of professional formation holds both breadth and application in equally valid positions.

Brenda, another junior faculty in the BME school, also reinforced the epistemological requirements of biomedical engineering as broadly based but also suggested that synthesis and application were equally as important. Brenda stated that biomedical engineers should know:

> …all the fundamentals of engineering disciplines, so strong in math and numeric analysis, but what's even more key is have a good understanding of how to apply those to particular problems, so biological problems…having the fundamentals of electrical and mechanical, biochemistry and organic chemistry, and being able to see how having that knowledge can enable them to do so much.

Brenda in contrast to Brian not only acknowledges that BME should know "fundamental of engineering disciplines" but she goes further by putting even greater normative importance on the understanding or knowledge of how to apply this broad knowledge base. Her use of "what's even more key" suggests a value statement that positions one goal (i.e., application) against the other (i.e., broad knowledge base). The problematic in this case is not allowing for both breadth and depth to exist in the same space and building communication formats that support both epistemological and ontological values.

For many participants, the value of biomedical engineering was the ability to integrate various disciplinary languages to produce some sort of impact to the human body or humanity in general. Holistic thinking, or the understanding how various systems interact, was a characteristic described as a distinguishing dimension of biomedical identity when compared to other engineering disciplines.

Biomedical engineering was constituted in/by the need to have knowledge of various engineering and science disciplines. The breadth of the field also called for biomedical engineers to find ways to synthesize various knowledge sets within biological contexts. Breadth, synthesis, and integration were held in contrast with the goal of developing specific skills to apply biomedical knowledge.

Goal of professional formation—realizing specific application.

For participants, the goal of building a broad knowledge base often came as a tradeoff with the goal of realizing the specific application of their work. The theme of specific application is defined as developing specific skills: (a) to learn how to apply a broad knowledge base, (b) to produce a desired outcome and provide impact, and (c) to be competitive in the professional marketplace. These subsets are not ordered or ranked in order of importance but moreso represent three areas by which participants articulated how developing specific skills enabled their professional formation.

First, participants—students in particular—explained that developing specific skills helped them learn how to apply the broad BME knowledge base. Students frequently described their experiences working on "real-world" projects where they were given a problem, parameters and forced to use or develop specific skills to solve. For instance, student participants explained their courses were also accompanied by a designated laboratory (lab). Students described how labs, similar to "real world" projects, enabled them to develop skills as a process for learning and applying a BME knowledge base. Macy in particular described how learning formats such as labs and projects influenced her overall professional formation experience. She was a sophomore and described the value of developing specific skills in more active learning formats such as labs:

> …you get in these classes, and here's all the information you could have to know. It's so much for your brain to take in, but then when you take that to lab or you take that to these projects, it's like, here's how we're actually going to use it.

> That's what you're going to end up remembering, and that's what you're going to end up using when you go into industry…

Macy's description revealed the relationship between developing specific skills and maintaining a broad knowledge base. She reinforced the problematic of a broad knowledge base was overwhelming amounts of information. This was evident in comments such as "It's [BME information] so much for your brain to take in…" However, translating this information into specific skills and applying these skills within a laboratory or project setting completed the professional formation process. That is, developing skills for application suggested a full professional formation experience from "how we're actually going to use it [information]", to "that's what you're going to end up remembering", and ultimately "that's what you're going to end up using when you go into industry."

Second, being able to see how their work impacted others was a primary reason participants entered the field. Helping people or impacting people's lives was a recurrent discursive phrase expressed by both students and FSA. In other words, a goal participants had in/by their professional formation was to develop the skills necessary to produce specific impact for people or people's lives. Braxton a junior faculty in the BME school described his motivation for entering the biomedical engineering discipline.

> …whatever I do, will need to have an impact in biomedical, in biomedicine. Either helping patients, or discover, make discoveries about the biological system…It's going to be about that what I'm going to do, how I'm going to make it, deliver it to the patient, to the people who will benefits from it, how, what can I do to maximize that benefit?

Braxton's goal in doing or being a biomedical engineer was to provide impact. He defined impact in practical terms such as "helping specific patients" or how "to deliver…to the patient". Braxton also discussed impact in theoretical terms, such as making "discovering about the biological system." However, broader biological discoveries were ultimately rooted in how people would benefit or how "to maximize that benefit." From on ontological perspective, doing or being a biomedical engineer meant providing impact.

For many participants the ability to impact humanity was an expectation of doing BME work. Similar to being able to connect and integrate multiple disciplines, being able to impact human lives – and to be able to see this impact—was a fundamental expectation for becoming a biomedical engineer. As Mickey, a senior in BME, described, "I guess at a basic level, not to slam MEs or anything, I guess BMEs have more of an impact on humanity, I guess, which is the reason why I initially decided to go the BME route." I argue that Mickey's need to distinguish his degree from mechanical engineering (ME) was rooted in his own desire to form a well-defined professional biomedical engineering ontology. That is, Mickey was able to better understand his own professional identity in opposition to other closely-related professional identities (i.e., mechanical engineering). Mickey discursively framed and differentiated biomedical engineering from mechanical engineering, highlighting that the fundamental difference was that biomedical engineers "have more of an impact on humanity." Mickey also discursively introduced normative assumptions in his identity maintenance, establishing biomedical engineering has having "*more* impact on humanity."

Witnessing impact also has important implications for diversity and inclusion. It is well-established in engineering education literature (Godfrey, 2015; Godfrey & Parker, 2010; Tonso, 2014; Trevelyan, 2010) that seeing impact is a large motivator for individuals from underrepresented groups—highlighting increased numbers of women and ethnic minorities in disciplines such as biomedical engineering (as compared to other engineering disciplines). And by consequence, lower numbers in less human-centered engineering disciplines such as electrical and computer engineering.

Seeing the impact of their work extended beyond helping people but also included, more broadly, seeing progress or change from one state to another. Seeing change could include improving an individual's health but could also include seeing a project progress and move forward from where it began. For instance, Maggie was a senior BME student and had several internship experiences in addition to various extracurricular experiences with student organizations. She was particularly involved with student organizations focused on global health initiatives. Throughout our interview, Maggie became especially passionate when discussing the possibilities BMEs had for impacting people and people's lives as well as the professional experiences that enabled her to contribute to innovation and development. She described one of her internship experiences:

> There was one aspect of my internship I especially enjoyed…I was given the opportunity to look at the process that they were using to create the materials…and revamp their process using current technologies. Make it more efficient…reduce the materials they had, reduce the amount of running time they had and just play with it…It was exciting because I was allowed to play around and create something new…

Maggie needed specific skills to meet her expectations of producing some sort of change or innovation. She was able to realize this expectation in her internship given the opportunity to "play around and create something new." That is, this particular internship experience provided her with an opportunity to develop the necessary skills to produce change and "create something new." The goal of realizing application was rooted in having the skills to produce change. Assuring that project work was simply "going smoothly" did not meet this participant's expectations for realizing the specific application of their work. Impact was constituted by creating or providing something new, innovating from the current to some new future state, and having the necessary skills to do so.

Finally, many participants explained that developing skill sets was critical for entering and surviving in the marketplace. Lectures as a communication format for building a broad knowledge base was a barrier for developing specific skills required in the marketplace. The lecture format presupposed the discipline to be constituted by its breadth moreso than by its specific application and contributed to a "jack-of-all-trades" discourse. This discourse showed to be problematic for students trying to differentiate themselves in a crowded marketplace. Mitch a sophomore was particularly sensitive to marketplace needs given his recent focus on searching for internships. He shared his interpretation of the field.

> What everybody says is, its [biomedical engineering] one of those "jack-of-all-trades, master of none" sort of disciplines. You get the introduction to mechanical, electrical, materials. You get an introductory understanding of medicine, anatomy, biology, but you're not really the best at any of those things.

In this case, the "best" meant being able to provide specialized expertise in any one disciplinary area (e.g., mechanical, electrical, material, medicine, anatomy, biology). That is, Mitch suggested that biomedical engineering would have to excel in one or more of these areas to be competitive in the marketplace. However, by excelling or being the "best" in any on of these areas would in fact take away from the ontological foundation of biomedical engineering which is constituted by the integration of all disciplines. The problematic rather is how can communication formats translate an integrative (i.e., one that embodies both breadth and depth) ontology (and epistemology) into professional identities that are both desired and relevant in the professional marketplace.

Mitch expanded on the jack-of-all-trades premise and distinguished the problematic against other similar engineering professions such as electrical engineering.

> That's [jack-of-all-trades] the biggest thing people sort of complain about, is that you're less hireable. A lot of the time, what people say is that corporations are looking for someone who is the best at one thing, so why hire a BME to design a circuit to go in an implant when you could hire an electrical engineer?

Throughout Mitch's description, he invoked a professional discourse that primarily valued specialization and commoditization. That is, according to these excerpts, there was not any space for a diversity of professional specialties or competencies but rather the marketplace expectation and norm was to demonstrate mastery in one particular area – that is, "the best at one thing".

However, Mitch in the same line of discussion described the idea of being broadly trained as distinguishing advantage. He explained how he viewed the breadth of the field as a strength.

> I think that's a reason I enjoy it [biomedical engineering] a lot, is that it gives you a bigger picture understanding…I can sort of see the bigger picture of everything that's going on in a more clear way and I feel like other people might not.

Mitch's limited time within the discipline may have contributed to an overly simplistic view of how biomedical engineers could practically and tactically leverage a "bigger picture understanding." That is, what does a "bigger picture" professional ontology look like in practice? There were few instances were participants parsed how having a bigger picture identity would serve them in the marketplace, similar to specialization expectations. In other words, there was not a "bigger picture" analog to Mitch's example that specialized engineers like electrical engineers are more attractive "to design a circuit to go in an implant."

The breadth-depth discourse was mostly maintained in advantages and disadvantages terms. That is, breadth is either problematic for developing differentiated skills or it is good because it enables a unique perspective. I argue, however, that in order to produce integrative and transcendent professional formation experiences the strategic use of communication formats is ideal for bringing both organizational realities together. In other words, how can the BME school strategically integrate communication formats to gain from both a broad knowledge base while also developing specific skills?

The biomedical engineering discourse community maintained the professional formation goal of building a broad knowledge base to be able to integrate multiple disciplinary expertise. Participants also acknowledged the goal of developing a comprehensive repertoire of technical skills. Developing skills enabled students in particular to learn how to apply “biomedical knowledge”. Skills also afforded participants a way to realize and produce impact in various ways. Students argued that specific technical skills development (e.g., designing in SolidWorks) was a primary way to enter the marketplace. These goals were discursively maintained as a tension in that developing skills was often times sacrificed in order to build a broad knowledge base.

At this point of my GPT analysis I have described the expressed goals of professional formation or the expectations of what stakeholders had for what professional designs should provide. Participants described that professional formation in biomedical engineering involved (a) building a broad knowledge base and (b) realizing specific application of their work. Acknowledging the goals of a particular design falls in line with the human-centered design’s first principle of design epistemology. This principle states that design knowledge is gained in understanding the individual elements of a design, the goal of the design, and how the design achieves its goal (Simon, 1969). The focus on identifying and understanding goals in/by design also fall within the principle of CaD that designs are hypotheses for how communication ought to work. Goals suggest the *ought* of a design.

In the next section I continue to unpack the individual element of professional formation designs and discuss the strategies participants enacted to achieve expressed goals of professional formation and the actions they took to address the tensions between both goals. I highlight how stakeholders navigated this dilemma and how the strategies they enacted challenged the ontological and epistemology presuppositions maintained by standard lecture formats. Surfacing what, why, and how participants chose to address problematics in professional formations provides the beginning of a design roadmap school administrators can use to build communication formats that presuppose a highly integrative and transcendent professional formation experience.

Technical strategies: Tactics for overcoming barriers to becoming

There were three primary strategies participants enacted to overcome the challenges in the professional formation experience. First, participants described how research participation provided context to apply broad knowledge while developing content-specific skills in a community of fellow practitioners. Second, students described how labs and design experiences provided similar contextual and community elements for cultivating content specific skills while also offering more opportunities for participation and ownership. Third, participants described one particular physiology course, the dynamics of which introduced a range of disciplinary knowledge while *also* enabling students to develop skills and contribute to a specific outcome.

Contextualizing BME information and developing skills in/by research participation.

Participating in undergraduate research was perhaps one of the more impactful ways students managed the tension of building a broad knowledge base while also contributing to specific application. Undergraduate research, as an activity, carries varying meanings in terms of how undergraduates are involved in the research process. At the BME school, faculty typically led research labs focused on their particular area of expertise. For instance, among many areas, there were labs dedicated to exploring drug delivery systems; to building deep learning and intelligent capabilities; or to understanding the mechanical properties of regenerative tissues. Undergraduate students who had interest in a lab's particular focus area could engage faculty to explore opportunities to work in the lab.

Undergraduate students would typically work within these research labs with a lead faculty member, graduate students, and any other collaborators in and outside of the school. Students would perform a wide variety of research activities including but not limited to running experiments, conducting literature reviews, analyzing data, and maintaining documentation. The faculty leading the research, as well as at the nature of research being conducted, mostly determined the type of research activity the student would perform. Research labs, similar to learning communities, study abroad, e-portfolios, and service learning is categorized as high impact experiences and shown to help develop the necessary skills to be successful in work and life (McNair & Albertine, 2012).

Many faculty members, such as Brenda, one of the junior faculty, viewed undergraduate research as a way to counteract the lack of specificity within current professional formation processes and provided students a communication format for contextualizing information while building specific technical skills. Brenda suggested that:

> What a lot of students…come away feeling broad and not deep. Students can get deep in other ways, but it's not necessarily through the straight curriculum…like undergraduate research is a phenomenal example. They go into a lab, learn all about ultrasound and image processing and really come away with a completely different skill set that they would have never really gotten in class. In my lab, they learn molecular biology and how to manipulate an organism to do what you want it do, and how to take that organism and make predictions about it, do mathematical modeling, really large scale sets of ordinary differential equations to predict dynamics of a system. They do that, they don't get that depth in a particular class.

Brenda provided an example of the type of research activities undergraduate students perform in her lab, such as, using "mathematical modeling, really large scale sets of ordinary differential equations to predict dynamics of a system." Through participating in research, Brenda's undergraduate students were able to take information from the standard curriculum, molecular biology in this case, and contextualize this information by learning "how to manipulate an organism" or how to make predictions about that organism. Students in/by building these specific skills were not only able to contextualize BME information but also build a highly technical skillset.

From the student perspective, undergraduate research was also viewed as a critical strategy for overcoming the challenges of a standard lecture curriculum. Marley reinforced the impact of undergraduate research had for professional formation above and beyond the standard curriculum.

> I know about biomechanics more from my research than I do the biomechanics class because I was not particularly impressed with our biomechanics class in sophomore year. I learned more about that from [lab professor] and research…It definitely doesn't all come from the degree. I feel like I've learned a lot from research and that aspect.

Undergraduate research as a communication format enabled him to develop a biomedical engineering ontology, create space for contextualizing biomechanical information, while also building specific biomechanical skills.

Research opportunities not only provided an opportunity to develop skills (e.g., manipulating organisms, predictive modeling) but also provided a context for *how* to learn how to develop these skills. The research context exposed students to a broad area of biomedical engineering (e.g., molecular biology) and the processes involved for developing specific skills and producing specific impact within a broader topic area. Students learned how to navigate going back and forth from their broad knowledge base to application within a specific context.

Cultivating content-specific knowledge through ownership.

Many students also described how critical labs and design experiences were for overcoming the challenges in professional formation. Labs offered many of the same advantages as undergrad research for overcoming challenges. Students were able to contextualize the broad knowledge gained in lecture while developing specific skills and contributing to some outcome. For instance, Marvin a sophomore in the BME school described what he was able to gain from his lab experiences.

> And then the labs, there are a lot of protocols that I learned that I didn't really know before. I learned how some things work. And then I think even more so, most people wouldn't have had prior research experience, so even more so for them I think that's really useful.

Protocols in this context were written procedures typically used to establish standardized methods for conducting experimental studies as well as how to properly use laboratory equipment. Merriam-Webster (2018) defines a protocol as "a detailed plan of a scientific or medical experiment, treatment, or procedure." Protocols served as a baseline for laboratory activity and served as technical guides for how to apply theoretical and abstract knowledge gained in lectures. Therefore, protocols (and more importantly, understanding how to work with protocols) served as vehicles for what constitutes biomedical engineering knowing, doing, and being.

Marvin had previous research experience working as a high school research intern at a local hospital and influenced his decision to pursue BME. This experience afforded him the opportunity to contextualize much of the information he gained in lectures as well as gain technical know-how skills. Marvin realized the importance of learning formats such as labs given his similar experiences with research (where he gained similar formative experiences). Marvin shared that labs were even more valuable for those who had not had previous research opportunities, "and then I think even more so, most people wouldn't have had prior research experience, so even more so for them I think that's really useful."

Differently than for undergraduate research opportunities, labs were required for students whereas research opportunities were primarily left to students' interest and initiative. Another distinguishing characteristic of the lab experience was the amount of ownership afforded to (and expected of) students. Students in undergraduate research, in many cases, were assigned projects, given parameters, and expected to report back. Lab work was designed to cultivate student's initiative and their ability to identify the boundaries of a problem, how to approach the problem, and the skills necessary to solve. Maggie commented on the level of student ownership involved in lab work.

> The practical work that we've done [labs] has always been more student initiative. We've had to go in and think about the problem and actually create it and learn about it. It's frustrating to think about when you first walk in first day of class. They're like, "Okay, here's your problem, go solve it." That's not fun, but when you really start working on it, it's very valuable.

Maggie suggested a powerful ontological formation process. Labs as a communication format presupposed the messiness and uncertainties of problem-solving, typical in the doing of biomedical engineering work. Students not only learned how to apply theoretical knowledge but were able to contextualize this knowledge in a setting where not all pieces of information were available, like Maggie shared, “They’re like, ‘Okay, here’s your problem, go solve it.” Students learned how to take ownership of understanding the nature of the problem, strategies for solving, and the skills needed to solve. By participating in their own solutions, students identified what skills were needed and how to develop these skills. Students understood that the becoming process not only involved social knowledge (problem-solving, critical-thinking), theoretical knowledge, and technical knowledge but the integration of these dimensions in the doing of biomedical engineering work.

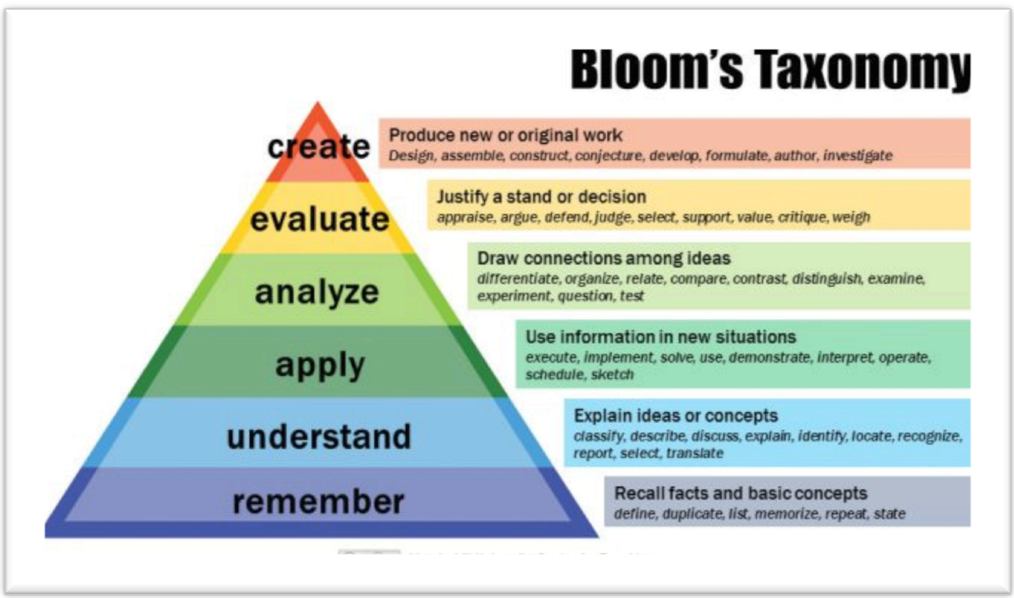
Michelle a sophomore in BME added to Maggie’s comments and provided further nuance to how technical know-how was developed in/by lab work. Michelle also revealed discursive values of what it meant to be a biomedical engineer and what biomedical engineers should know.

> Our lab classes are probably one of my favorite in terms of learning, because you learn so much so quickly and so short of a time, and it’s really useful. It’s a lot to be thrown at for a one credit class, but I mean, right now we’re even designing our own experiments. I mean having to create the procedures themselves and look up all of the articles that already exist on it to determine what’s the best route of taking it, to what inventory supplies and then to have to go through all of the procedures correctly…with the correct…Standard operating procedures in these kinds of things. I feel that’s particularly helpful as well as having to keep your work documented so that way you can write the report at the end.

As I disentangled Michelle’s comments I uncovered several practical, epistemological, and ontological values discursively maintained by labs (as a communication format). Michelle shared that lab classes were her favorite “because you learn so much so quickly and so short of a time.” Michelle’s comments described processes of cognitive learning (Zimmerman, 1989). I would argue that students also learn in lectures "so much quickly" and in a short period of time, however, students rarely described lectures as their "favorite in terms of learning." Michelle revealed that documentation, standardized procedures, and sound decision-making were practical values in professional formation. That is, these areas were values for the *doing* of biomedical engineering work. In addition, she revealed that taking ownership in developing and mastering these values, in and by itself, was also an ontological value of becoming. She shared that "we're even designing our own experiments…create the procedures themselves…determine what's the best route of taking it…then to have to go through all of the procedures correctly." What she described was a professional formation process that afforded both how to build technical know-how and how to build ownership in the process of becoming a biomedical engineer.

Labs, similar to lectures or undergraduate research, were communication sites that shaped and constituted the discursive professional formation of biomedical engineers. Labs as a communication format presupposed what it meant to become a biomedical engineer not only in the discursive practices by stakeholders but also by the design of the format. For instance, Michelle described a substantial volume of technical know-how introduced and gained in/by lab work all for a one credit course, "because you learn so much so quickly…It's a lot to be thrown at for a one credit class." Whereas lectures (a more theoretical-based learning format) are typically worth three credits, what sort of epistemological and ontological values are being maintained given these different formats?

Michelle's comments also presented how professional formation designs such as lectures and labs afforded varying levels of learning efficiency and transferability. Whereas both lectures and labs presented a high volume information, lectures were given more time than labs and students like Michelle (in labs) came away with a deeper understanding of key concepts while also being able to transfer this knowledge into practical skills (e.g., transferability). The notion of efficiency and transferability follows well-studied models of learning such as Bloom's taxonomy (Anderson, Krathwohl, & Bloom, 2001). Figure 3 describes the levels of Bloom's framework beginning at early stages of learning (remember) and moving towards high-order learning (create). Michelle's comments revealed how labs, despite being given less credit hours (e.g., 1 credit hours vs 3 credit hours), maintained high expectations for performance and pushed students to reach higher-order and transferable learning objectives such as applying, analyzing, evaluating, and creating biomedical engineering-related concepts.



Open source: Vanderbilt Center of Teaching.

Figure 3: Bloom's Taxonomy

Design experiences were equally as valuable for many students. The Biomedical School was unique in how design and capstone courses were structured, in comparison to other engineering schools at the university. Most engineering schools included one senior design or capstone course where students in their last year would develop an individual device or system.

The BME School promoted a structure where students took design-based projects beginning in their second year that, in theory, prepared them for their senior design projects. Aside from design projects in students' beginning courses, the BME school (differently than other engineering schools) had students begin their senior design projects during their junior years. Students in the last semester of their junior year began a process of ideation and project creation by conducting various clinical and professional informational interviews as well as designing a "product development proposal (PDP) for their senior design projects" (University BME, 2019). The BME school site (University BME, 2019) described their unique approach:

> The full ideation stage for senior design projects begins in the spring semester of the third year of the program when junior level students gather many ideas from interviews with clinical professionals and visits to clinical settings both locally and internationally. In this course, faculty members and external mentors guide student teams through developing a product development proposal (PDP) for their senior design projects. In the summer, students entering their fourth year (seniors) select from the final list of approved projects one project team that best meets their career interests and skills. We create even more diverse project teams by inviting students from other engineering schools such as mechanical, electrical, materials, etc. to participate.
>
> In senior design, the students develop and test their prototypes toward verification and validation. During this semester teams create a design history file (DHF) to successfully document the development of their device or system and demonstrate that their solution effectively addresses real patient, clinical, and health-care system needs.

I suggested previously that the school promoted (rather than actualized) a seamless process of building skills and competencies leading to their senior design projects. The reason being that many students did not necessarily feel that the design of the curriculum in practice afforded all the skills needed to prepare for their senior design projects. For example, Melvin shared that "then people get to senior design and nobody knows what they're doing." The level of contrast between the intention of the curriculum structure design and student's realities was further evidenced in comments made by one of the BME faculty in the BME School's 2017 news releases. She stated:

> We prepare them well for doing data-driven designs in the lower course requirements and labs…We teach them the design skills they need in other courses. Then they get to senior design and realize that they have been designing all along.

Despite the professional formation tensions and contradictions embedded in how design experiences were structured, students in practice were given a greater degree of ownership than they were given in other learning formats, such as labs or undergrad research opportunities. Students were focused on tackling a specific problem throughout the duration of a design project. For example, Maggie described how a design-based course project was instrumental in the process of becoming a biomedical engineer:

> Our TA…gave us an opportunity to come in and create technologies and from whatever we learned in class, create little medical devices and see how that would go in to work. That helped me a lot…I really enjoyed it because I'm a visual person, I like seeing things work in front of my eyes…it didn't really sit in my head until I saw that happen in front of me. That sort of thing was really fun. That gave me an idea of, I could put devices together and make circuits work to do this kind of thing. It's one of those things that, those modules, that I remembered from there, I feel like those ideas or principles can be applied elsewhere. That to me was very valuable.

Opportunities to create devices and technologies were given to all students in these courses and appealed to many students like Maggie who joined engineering for the "hands-on" and tangible experiences. Engineering education research (Godfrey, 2015; Tonso, 2007, Trevelyan, 2010) in particular points to dominant learning strategies and preferences of engineering students, visual and kinesthetic learning being among the highest forms of engineering learning.

Maggie revealed important ontological factors afforded in/by design experiences. She explained how the visual and kinesthetic dimensions of design projects were critical for her professional formation, "it didn't really sit in my head until I saw that happen in front of me." This finding supported studies in engineering education (Godfrey, 2015; Lucas & Hanson, 2016; Tonso, 2007, Trevelyan, 2010) that discuss how engineers are typical visual and "hands-on" learners and doers.

Maggie's comments also revealed that becoming required an opportunity for testing theoretical knowledge, "whatever we learned in class", as well as the freedom to see how experimenting led to certain outcomes in her work. An opportunity for exploration and experimentation engendered how theoretical knowledge was applied in practice. Moreover, taking ownership over the process of experimentation and exploration, "how that would go in to work", created pathways for Maggie to see how to link theoretical knowledge to practice in other future contexts. In other words, design experiences, similar to lab work and undergraduate research, cultivated a professional ontology that went above and beyond the theoretical or technical dimensions of biomedical engineering and into a more integrated and possibly transcendent process of professional formation. As she suggested, "It's one of those things that, those modules, that I remember from there, I feel like those ideas or principles can be applied elsewhere."

This excerpt is a perfect example of situated learning elements that surfaced as students described how they overcame challenges in professional formation. Maggie valued learning formats where she was able to master the content while engaging in the messy process of negotiating the meanings of the problem, the application of knowledge, and the impact of possible solutions. Importantly for professional formation, this student was able to reflect upon the translational impact of this learning experience and how they could/would carry what they learned to other future contexts of their career.

Ultimately, labs and design experiences provided the context and environment participants could move back and forth between the broadness of their knowledge base and how to develop specific skills and applications of their work. In doing so, learners were active participants in the ongoing negotiations of the situation, problem, approaches, and implications. Participating in the daily, lived experience of doing biomedical engineering contributed to the sort of socio-technical knowledge of the discipline that standard lecture curriculum was ill-equipped to provide. That is, active participation of doing BME work served as bridge between the epistemological and ontological assumption of the discipline.

Undergraduate research, lab work, and design experiences were learning formats (sites of communication) and strategies invoked to overcome challenges in professional formation. These formats often stood in contrast to barriers attributed to traditional lecture formats. The final strategy that emerged from my analysis was in fact maintained by a traditional lecture format.

“Emphasizing the engineer” in a physiology lecture.

The school’s legacy physiology course was a widely acclaimed learning experience for many students. The course provided an introduction to medical concepts and physiological systems, such as, cardiovascular, pulmonary, and renal (University BME, 2019). The course was primarily a lecture format but was structured around problem sets or case studies that focused specifically on a specific biomedical problem, issue, or procedure in “the context of human disease, injury, and illness” (University BME, 2019). Students were required to complete extensive case studies that mimicked real-life biomedical problems and primarily worked in groups. In groups, students tackled these problem sets and case studies while developing skills in mathematical modeling (algorithmic coding), problem solving strategies, and proper documentation methods.

The course circumvented many of the professional formation challenges presented in/by traditional lecture formats. The assigned case studies/problem sets in addition to the professor's use of examples, metaphors, and narratives provided context and frameworks for how theoretical knowledge was applied in practice. The design of the course provided an opportunity for students to actively participate in the "doing" and application of biomedical engineering work while also introducing a broader theoretical knowledge base. Mackenzie, a sophomore in BME, shared how the physiology course was among the most critical learning formats of her professional formation.

> And actually in one of my classes right now, our anatomy [physiology] class we do something like that, it's just a lot more intense case studies. They take a lot longer to do. And I like prefer things like that because it definitely emphasizes the engineer. It's not just an anatomy class, but we're also in BME and here's like a problem set. Like you have to code – we recently coded…like a arm cuff for a blood pressure and we coded how it effects the artery and the inclusion of the artery, So I think aspects like that like reemphasizes the engineering in our education rather than just the material.

Mackenzie shared that she preferred the physiology course's "intense case studies" because they reemphasized the engineering in her education, "rather than just the material" in standard lecture formats. Her comments were a strong statement of the ontological and epistemological influence engendered by the course's case studies. Therefore, it is important to disentangle the elements of the case studies and how this particular learning format presupposed and emphasized "the engineer."

Case studies in the physiology course, as Mackenzie intimated, were designed to integrate concepts in biology, medical devices, engineering and understand how these various concepts interacted to address human health. The particular case study Mackenzie described had students mathematically model a particular method for reading blood pressure (i.e., the auscultatory method). For this particular problem set, students needed to know the cardiovascular biological system to understand how the artery in the arm interacted with a medical device such as a blood pressure arm cuff. Students needed to know engineering and mathematics principles in order to code and mathematically model the interaction between the arm cuff and the artery. Simply put, "emphasizing the engineer" meant: (a) working through a specific problem (i.e., the auscultatory method for blood pressure readings), (b) utilizing specific technical skills (e.g., mathematical modeling and coding), (c) within a human health context, and (d) working with both biological systems (e.g., cardiovascular) and medical devices (e.g., blood pressure cuff).

Lecture based curriculum that provided "just the material" stood in contrast to case study formats that "emphasized the engineer." Standard lecture curriculum created a void in the utility, application, and impact of doing biomedical engineering work—rather than being seen as foundational and/or complementary. The discourse maintained by both learning formats reinforced the balancing metaphor whereby active learning contexts (i.e., case studies) emphasized the engineer and lectures provided just the material. I argue that integrative and transcendent professional formation processes require communication formats that hold both discourses together as equally important and relevant.

The physiology course's case studies cultivated theoretical and technical ontological processes. These case studies were also structured as group projects which afforded a socio-technical layer of "emphasizing the engineering." Michelle shared how the course played such an important role in professional formation.

> I think probably the most common phrase…"Any class you can take with [professor] to take it". He is a character, he's been here since the beginning…we

> just finished the 44 page report on the auscultatory method of blood pressure readings…It's very group work heavy…Working together to solve all these complex problems and turn them into a reproducible output…That was a crazy intense project and I'm looking forward to the next…group work is really crucial, because you tend to, when you hear a problem, you have, like one idea that pops up first, and you kinda feel like that's the best idea, but when you have all of those other ideas on the table, you can kind of pick and choose and make an even better plan overall, and that class really is helping us work on that and work on our teamwork skills… And he just, he'll just sit there and he'll go through all of this information, but he tells it in stories, and he's got all of these funny anecdotes and different ways of memorizing this mnemonic…So it's really effective.

The physiology course gave students an opportunity to recognize the integral nature of collaboration in being and doing biomedical engineering while at the same time developing theoretical and technical knowledge sets. For Michelle, she recognized how critical it was to ideate various possible solutions in order to optimize the best output. For instance, she argued that "when you have all of those other ideas on the table, you can kind of pick and choose and make an even better plan overall, and that class really is helping us work on that and work on our teamwork skills." By structuring the case studies as group projects, students like Michelle were able to build competencies for managing more effective collaborations and, by consequence, potentially more optimized project outcomes.

The case studies for this course facilitated collaboration and "emphasized engineering" in the same way as the integration of biological and engineering principles emphasized the engineer. Being a biomedical engineer was being able to integrate multiple biological, engineering, and medical concepts while also navigating the social dynamics of engineering project teams. The physiology course, as a communication format, discursively maintained these epistemological and ontological values of biomedical engineering contributing to more defined identity anchors.

The professor's teaching style was also a distinguishing characteristic of the physiology course (the course as a communication site for professional formation). Michelle shared that the professor would "go through all of this information, but he tells it in stories, and he's got all of these funny anecdotes and different ways of memorizing this mnemonic…" Through a combination of narrative and other rhetoric devices (e.g., mnemonics) the professor implemented effective strategies and tactics for processing substantial amounts of information.

The physiology course focused on the integration of key ontological and epistemological dimensions of biomedical engineering and provided an opportunity to practice these critical dimensions of professional formation. The course, as a communication format, presupposed biomedical engineering as not only requiring knowledge in biology, medical devices, engineering, and collaboration but rather the integration of these various knowledge sets.

In this analysis I uncovered communication sites of professional formation, such as, lectures, undergraduate research, lab and design participation, and a particular physiology course. Each communication format presupposed and contributed to biomedical engineering ontology and epistemology in similar and different ways. Particularly, I found that lecture formats produced challenges in professional formation such as maintaining biomedical engineering ontology and epistemology that was too broadly based and limited students from developing specific technical skillsets that could be used in the marketplace. I also uncovered a discourse that positioned active learning formats (e.g., undergrad research, lab and design participation) against lecture formats in that one was better than the other or that there were only strictly advantages and disadvantages of each format rather than seeing formats as complementary and integral to a cohesive professional formation process.

Undergraduate research, labs, and the physiology course were communication designs and, specifically, designs of professional formation. Jackson (1998, 2002) and Harrison (2014) were interested in communicative designs (e.g., an online dialogue protocol, student grievance process), the goals purported in/by these designs, and the actualized practices of these designs (i.e., how these designs were actually enacted). Similar to these studies, the current findings showed how lecture designs were able to meet the goal of building a broad knowledge base while other designs, such as labs and undergraduate research, were described as formats specifically for realizing specific applications. Through analyses of participants' quotes, I uncovered how these designs in isolation were able to meet goals individually but did not produce an integrative and transcendent design of professional formation—one that embodied both goals inclusively throughout the learning process.

Also, and in contrast from previous CaD work, the current study showed how the enactment of professional formation designs engendered implications for biomedical ontology, epistemology, and professional formation. That is, I described the extent to which communication designs were significant and important sites of professional identity formation. Thus, understanding the intended professional goals of participants alongside the goals of the communication designs advances knowledge for the ontological implications of professional formation.

Participants described using undergraduate research, lab and design participation, and the physiological course as strategies for overcoming challenges in the professional formation process. The normative rationale for these strategies resembled situated learning frameworks and I argue that situated learning characteristics in combination with traditional lecture are the basis for transcendent ways of thinking, doing, practicing, and valuing both broad knowledge and specific application.

Philosophical rationale: Situated learning as a part of the professional formation process

Highlighting a combination of research opportunities, lab and design experiences—and one particular physiology course, participants described a holistic and multi-faceted, collection of learning experiences that stood in contrast to the challenges of relying solely on traditional lecture instruction. These learning experiences displayed many similar characteristics found in situated learning models (Lave, 1988; Lave & Wenger, 1990; Brown et al., 1989; Stein, 1998), providing the social, cognitive, and material environments (Stein, 1998) for doing biomedical engineering work and becoming biomedical engineers. The descriptions of the situated learning experiences offer a consistent philosophical rationale for navigating a broad knowledge base while also realizing the specific application of their work.

Although the philosophical rationale found in this study maintained its own distinct dimensions and characteristics, it is important to surface similarities to situated learning perspectives (Lave, 1988; Lave & Wenger, 1990; Brown et al., 1989; Stein, 1998). Doing so can bring to light practical and theoretical characteristics that can serve as design criteria for building normatively, pragmatic and locally situated professional formation processes.

At the broadest level, situated learning defines learning as a process of creating and negotiating meaning in the day-to-day experiences of a particular practice (e.g., biomedical engineering) (Lave, 1988; Lave & Wenger, 1990; Brown et al., 1989; Stein, 1998). Accordingly, learning is a continuous, ongoing negotiation involving factual knowledge, learners, environment, experts, community members, and social interaction. Knowledge and "learning is the result of a social process encompassing ways of thinking, perceiving, problem solving, and interacting in addition to declarative and procedural knowledge" (Stein, 1998, para. 3). Learning therefore is not separated by the messiness of relationships, social interaction, and environment–rather, it is constituted by them.

Situated learning emphasizes the application rather than the retention of content. *Content* involves specific facts and procedural knowledge (i.e., technical knowledge). However, it is the generative power of social interaction and context that provides meaningfulness of this technical knowledge and that ultimately corresponds to its utility. *Context* provides the setting for the messiness of learning. Context involves all the many values, beliefs, environmental cues that influence and provide meaning for content (Lave, 1988; Lave & Wenger, 1990; Brown et al., 1989; Stein, 1998). While context provides the setting, the *community* of learners provides the social interaction whereby learners negotiate the meaning of the task at hand, relevant content, and diverse approaches for problem solving. Communities negotiate the meaning of situated problematics, attempts at problem solving through encountering diverse views and perspectives. Finally, *participation* illuminates the communicative ways community members can produce, maintain, and challenge disciplinary assumptions.

Articulations and descriptions of each learning experience (i.e., undergrad research, lab and design, and the physiology course) displayed the overarching situated learning characteristics—that is, content, context, community, and participation. These learning experiences provided context and an environment where participants could engage with the messy process of doing biomedical engineering work. Students were able to identify and establish what elements of their broad knowledge were needed given the situation. Participating and taking ownership in these learning experiences exposed students to the intersection of the technical engineering content and the social dimensions of engineering (i.e., collaborating to iterate on optimal solutions). As part of a community, learners worked together to understand the nature of problems, developed approaches for solutions, and developed the necessary skills for a particular solution. In each unique situation, participants not only learned how to approach a particular situation and problem but also learned how to become a biomedical engineer.

The technical strategies I described in my analysis, alongside the philosophical rationale for these choices, draws parallels with the second human-centered principle of design epistemology. The second principle states designers should be reflective practitioners which underscores how design is enacted and communicated. Doing so can shape what is known and what can be known about design (Schön, 1983). The bulk of this study is an exercise of reflection on how professional formation designs are enacted, communicated, and what is communicated by these designs (i.e., what does each design presuppose about communication, discourse, and formation?). Similarly, this analysis also coincides with the third principle of design epistemology that knowledge is produced in understanding the move(s) from a current state to some other preferred state or ideal (Aakhus, 2007; Jackson & Aakhus, 2014; Jones, 1992). In this study, I unpacked the move(s) participants took to more precisely meet their expectations and goals of professional formation designs. Faced with a dilemma between a broad knowledge and realizing specific application participants described and suggested an integrated pathway of situated learning experiences (e.g., undergrad research, labs) *and* lecture formats. The preferred state, suggested in/by participants' design moves, is a professional formation process and state that is transcendent, integrative, and innovative.

Summary of findings

The tension between gaining a broad knowledge base and realizing the specific application of their work shaped and constituted the process of becoming a biomedical engineer.

Whereas the standard curriculum provided critical content in the formation process, realizing specific application often came at a cost for gaining a broad knowledge base. However, my analysis showed that participants who engaged with the lecture curriculum as *one* component of an entire becoming process—a process that also included several situated learning experiences—discovered relevant pathways in which to deepen their disciplinary knowledge while also developing specific applicable skills. Participants who enacted an integrative strategy were able to reach both goals of building a broad knowledge base and finding pathways for realizing specific application of BME knowledge.

These findings provide a practical-normative rationale for how participants constituted and conceptualized the process of *becoming* a biomedical engineer. Illuminating and investing into the conversations, practices, and pathways guided by a situated learning rationale may build formative processes that are both theoretically and practically grounded. Taking these findings related to professional formation into consideration, I turn to the next chapter and layout this study's theoretical contributions and practical implications.

CHAPTER 5: DISCUSSION

This study contributed to organizational communication and engineering education through the use of Grounded Practical Theory (GPT) (Craig & Tracy, 1995), specifically, and design principles, more broadly. This study's findings extended the use of GPT applying them to the process of becoming a biomedical engineer. Findings contributed to Communication as Design (CaD) (Aakhus, 2007; Aakhus & Jackson, 2005; Jackson & Aakhus, 2014) by revealing professional formation choices participants made and the communication formats that came together to presuppose biomedical engineering ontology and epistemology in professional formation. Leveraging the insight provided by GPT, findings also pointed to a unique perspective of Human Centered Design (HCD) (Krippendorf, 2006). I discuss how understanding the goals, problems, and strategies in the generative processes of professional formation introduced a distinct dimension of "humanness" in human-centered design—one that is normatively and pragmatically situated.

In this chapter, I first discuss (a) theoretical contributions, highlighting how this study contributed specifically to GPT, CaD, and HCD. I then (b) describe some of the study limitations, followed by (c) theoretical implications and future research directions. This study's (d) practical implications come next and involve the (1) implications for professional preparation, diversity, and inclusion, (2) design criteria for professional formation of engineers, and a (3) design roadmap for implementation. I conclude with a brief summary of the chapter and the overall dissertation project.

Theoretical contributions

Similar to Kuhn's (2008) alternative communicative theory of the firm, this study shows how Grounded Practical Theory (GPT), Communication as Design (CaD), and Human-Centered Design (HCD) offer novel ways to conceptualize the processes of professional formation. Specifically, this study introduces a unique approach to problems of professional formation: 1) the gap between what students learn in universities and what they practice upon graduation; 2) the perception that engineering is solely technical, math, and theory oriented; and 3) the lack of diversity and inclusion (incorporation of difference in perspectives, values, and ways of thinking and being engineers) in many engineering programs. These issues are critical to the professional formation of engineers and have yet to be explored from a truly holistic or integrative approach. A view of professional formation that approaches problems of professional formation as interconnected and involving core issues of identity, knowledge, culture, and curriculum.

I argue that existing models have produced simplified assumptions and narrow understandings of the various underlying and interconnected concepts of professional formation. Current models of professional formation are not wrong or invalid, rather limited in scope and thus unable to capture the highly integrative and wickedness of problems related to the professional formation of engineers.

This study offered, in the same way as Kuhn (2008) did, "an early step – a rationale, an agenda for further development, and a set of issues to pursue" (p. 1247). In order to include and address the range of conceptual elements, dilemmas, goals, and strategies in/by professional formation, there needs to be a view that involves detailed knowledge of these organizing processes that make up and contribute to ontological and epistemological foundations of professional formation. Offering such an inclusive perspective, this study appeals to researchers of professional formation across various disciplines. In the following section, I layout the theoretical contributions of GPT, CaD, and HCD frameworks and how these lens', individually and collectively, helped provide a more holistic and integrative view of professional formation.

Grounded practical theory (GPT).

This study showed how grounded practical theory offers a different and important way to conceptualize professional formation. Typical grounded practical theory studies (Aakhus 2007; Bloom, 2014; Guttman, 2007; Harrison, 2014; Koening et al., 2014) focus on the everyday instances of "talk" highlighting how participants revealed the underlying, philosophical rationale for their communicative choices. Studies guided by a grounded practical theory methodology focus primarily on a particular communicative setting, format, or interaction (e.g., doctor-patient exchange, online discussion forum) and point to the goals, problems, and communicative strategies participants enacted within those settings.

This study, guided by the principles of grounded practical theory, focused on everyday discursive practices of a biomedical engineering community highlighting how participants revealed the underlying, philosophical rationale for their professional formation choices. I showed how grounded practical theory helped point to contradictory and seemingly irreconcilable problems in professional formation—in this case, the problem of building a broad knowledge base while also realizing the specific application of biomedical engineers' work. Applying a grounded practical theory framework unpacked strategies which enabled participants to accomplish both professional formation goals and the rationale for enacting these strategies. Applied to professional formation, GPT revealed the entangled web of engineering culture, curriculum, and marketplace expectations. GPT especially pointed to the deeply integrated relationship between the ontological and epistemological foundations of biomedical engineering professional formation. That is, becoming a biomedical engineer meant having knowledge of several sets of disciplinary expertise while also understanding when and how to enact this knowledge in practice. This level of insight broadened the aperture of GPT principles, deepening the theoretical framework's epistemological and ontological contributions while also expanding its utility as a normative, pragmatic mode for exploring and uniquely conceptualizing professional formation.

Grounded practical theory (Craig & Tracy, 1995) is built on the assumption that "communication problems typically arise because communicators pursue multiple, competing goals or purposes such that conflicts among goals often emerge to block ongoing discourse…" (p. 254). The interrelated problems that emerged in the current study centered on a biomedical engineering ontology and epistemology that was viewed as too broadly based. Biomedical engineering identity was fueled by problems of "learning everything and learning nothing" and limited opportunities for developing specific and practical skills that could be used to provide impact and be competitive in the marketplace. These problems were amplified by standard lecture curricula that did not provide an environment or opportunities for participating in establishing the situated meaning of highly technical biomedical engineering content. As such, participation in, or reliance on, the communication format of lecture curricula constituted and contributed to a "jack-of-all-trades" identity that showed to be problematic for professional formation. Given the dilemma found in this study, findings revealed how participation in organizational and learning processes (e.g., undergraduate research, physiology course design, lab and design formats) allowed learners to navigate, negotiate, and move back and forth between gaining a broad knowledge base and realizing specific application.

Specifically, in response to the potentially irreconcilable challenges presented in/by professional formation at the school, participants invested in processes that constituted a professional biomedical engineering identity that was more closely aligned with the demands of the marketplace. These processes and strategies included undergraduate research, labs experiences, and the design of the school's physiology course. Building on grounded practical theory, these strategies represented a process of constitutive reconstruction. In the process of reconstruction, the reasoning mechanisms for generative, constitutive, and communicative practices were revealed. Craig and Tracy (1995) argue, "the purpose of…reconstruction is not to discover some inherent, unchanging "essence" but rather to construct a tentative, revisable, but still rationally warranted normative model that is relevant to a broad range of practical situations" (p. 252).

The normative model that was revealed in my analysis was a reconstruction that closely resembled situated learning theories (Brown et al., 1989; Lave, 1988; Lave & Wenger, 1990; Stein, 1998). That is, participants' articulations of and rationales for engaging in strategies, such as, undergraduate research, labs experiences, and the school's physiology course highlighted the key characteristics of situated learning. These experiences allowed participants to engage with the technical content of their discipline in an environment and culture that enabled them to actively participate in and negotiate the meaning of the content within their immediate situation. Participants were able to develop biomedical engineering ontology and epistemology that helped navigate through substantial amounts of biomedical information and also develop specific skills to enact the doing of biomedical engineering work. The result was developing a biomedical engineering identity that held together seemingly irreconcilable opposites—gaining a broad knowledge base while also realizing specific technical know-how.

Communication as Design (CaD).

This study also showed how layering a Communication as Design (CaD) lens offered a unique way for conceptualizing and understanding the process of professional formation. An assumption of Communication as Design (CaD) is that *designs for communication are hypotheses* for how communication ought to work. Designs for communication in the present study referred to learning formats such as lectures, undergraduate research, lab and design experiences, and the school's physiology course. Each format presupposed something about communication, or more specifically, each format presupposed something about how professional biomedical engineering ontology and epistemology were constituted, communicatively. Each professional formation *design for communication* presupposed something about the recurrent practices held within the school and how these recurrent practices constituted professional ontology and epistemology in ways that were both enabling and problematic.

Interactivity is a critical element of *designs for communication* in that a particular design presupposes how communication ought to work by shaping interactivity—and as a result shaping the constitutive impact of communication. Given the affordances and constraints of this study's designs for communication (e.g., lectures, undergraduate research, lab and design experiences, and the school's physiology course), interactivity in and by each format shaped and maintained how communication *ought* to have worked in the professional formation process.

Specifically, findings showed how lecture formats shaped and maintained biomedical engineering ontology and epistemology, characterized by a broad knowledge base that often times came at the expense of gaining specialized technical know-how. The lecture format's dominant affordance was providing high volumes of information while the most salient constraint was the limited opportunity to operationalize and practice the information gained. The professional epistemological and ontological outcome was an identity constituted by a wide knowledge base but not deep in professional practice. The most visible problematic was that students were viewed as leaving the undergraduate program with a broadly-based set of experiences and not in the best position to enter and compete in the biomedical engineering professional marketplace.

Situated learning formats (e.g., undergraduate research, labs, design experiences), on the other hand, maintained interactivity constituted in/by application and opportunities for developing technical know-how. Students developed specific technical skills, such as, learning how to follow lab protocols or opportunities for learning specific design software packages (e.g., AutoCad). However, situated learning formats in and by themselves did not expose students to the breadth of biomedical information that was a distinguishing ontological characteristic for becoming a biomedical engineering.

However, lectures *and* situated learning formats, strategically integrated in an undergraduate curriculum, presupposed biomedical engineering knowledge that was relevant, dynamic, and inclusive. Strategic integration of both communication formats led to practices more amenable to the breadth of biomedical engineering epistemology while also creating space for ongoing technical skills development and application. The integration of situated learning and lecture formats shaped a biomedical engineering epistemology that was viewed to be more aligned with an increasingly competitive professional marketplace, a marketplace that demanded an integrative mindset but also demonstrable and specialized technical competencies. Ontologically, strategically integrated communication formats, led to a biomedical engineering identity that embodied participants' expectations of creating impact, technical competence, and marketplace differentiation. Lecture formats afforded a wide knowledge base that students were able to refer to and further develop throughout varied situated learning formats. For example, a student in undergraduate research could refer back to their baseline understanding of mathematics and differential equations and further develop these skills by mathematically modeling the dynamics of specific organisms. The outcome was an epistemological base that was both wide and deep and a professional identity that was differentiated and rooted in impact and technical competence.

Layering a Communication as Design (CaD) lens is also theoretical in design's ability to be reflective. CaD is reflective about "the successes, failures, and surprises of designs…reflecting upon and theorizing communication" (Aakhus, 2007, p. 115). Using a CaD lens I uncovered successes, failures, and surprises of communication designs and implications for the discursive production of professional formation, identity, and knowledge. Specifically, the CaD framework illustrated how the lecture format, as a communication site, in and by itself, was in many ways perceived as a failure for the professional formation of engineers. The lecture format did not create space for participants to meet their professional formation expectations and left many feeling broadly-based but not practically-oriented. I found that situated learning formats created an identity of professional practice but in and by itself lacked the breadth required in and by the biomedical engineering discipline.

The surprises that a CaD lens uncovered was that by strategically integrating lecture and situated learning formats, the school curriculum did and could continue to provide professional formation experiences that involved integrative thinking, doing, practicing, and valuing of both broad knowledge *and* specific application. That is, lecture or situated learning formats by themselves did not constitute transcendent professional ontology and epistemology. Reflection of successes, failures, and surprises of communication designs of professional formation showed how interactivity shaped and constituted biomedical engineering ontology and epistemology in the professional formation process.

Leveraging a CaD lens, I was able to show how designs for communications, in this case learning formats, and interactivity served as powerful vehicles for the discursive epistemological and ontological construction of professional formation. Doing so especially elucidated the possibilities for intentional intervention of interactivity and the constitutive forces in professional formation.

Human-centered design (HCD).

This study showed how taking a human-centered design lens offered a unique way for conceptualizing professional formation. Exploring designs for communication brought to life the ways participants, through interactivity, actively designed discourses of professional formation in an attempt to achieve and meet their epistemological and ontological goals. The process of reconstruction (Craig & Tracy, 1995) resembled Krippendorf's (2006) suggestion that "communication designers" have a role in reconstructing discourses in an attempt to achieve some desired end state. The process of reconstructing discourses draws many parallels with human-centered design.

In the present study, the aim was a process of professional formation that was more aligned with both goals of breadth and depth in biomedical engineering formation. Participants showed how by leveraging and strategically integrating both lecture and situated learning formats they were able to constitute a professional ontology and epistemology indicative of the complex web of engineering culture, curriculum, marketplace expectations and discourses of inclusive communities.

Specifically, a human-centered design lens afforded three critical perspectives for the professional formation of engineers. First, a principle of HCD acknowledges the role of language in the construction of diverse community-specific worlds (Krippendorf, 2006). Given this study's communicative approach, I illustrated how professional formation talk impacted how participants enacted the process of becoming an engineer. For instance, lectures constituted professional ontology and epistemology as rooted in breadth and lacking the specificity of practice. As such, professional formation in/by lecture formats influenced many students to seek out situated learning formats (e.g., undergraduate research, labs) as the places where "you learn the most" about how to be a biomedical engineer. The discourse of what it means to be a biomedical engineer afforded by the various communication formats played a significant role in the construction of community-specific, professional formation.

Second, a principle of HCD is that people use designs in their own terms (Krippendorf, 2006). Leveraging a HCD perspective, I showed how participants interacted with designs of professional formation to reach their epistemological and ontological goals. Participants used professional formation designs in their terms to strategically integrate a professional formation process that was rooted in both depth and breadth. Lecture designs provided the breadth of information, whereas, situated learning experiences provided opportunities for not only technical depth but also for developing differentiated ontological anchors for what it meant to be a biomedical engineer.

Last, and relatedly, a HCD perspective highlights the processes of (re)constructing artificial worlds whose sole purpose is to design artifacts that make sense, that are useful, and welcoming for stakeholders (Krippendorf, 2006). I examined how participants, through the strategic use of multiple design formats, actively engaged in the reconstruction of becoming an engineer. I argue that it was the strategic integration of both lecture and active learning formats that reconstructed the ontological process of becoming. That is, I found that curriculum-based lectures and labs were only one component in the professional formation. A more complete and inclusive ontological and epistemological foundation was laid when these formats were combined with situated learning designs such as undergraduate research and other design-based learning experiences. The process of reconstruction of the community-specific world of professional formation, within this particular school, revealed the design artifacts that made the most sense, were useful, and most welcoming for stakeholders.

Uncovering the constitutive features of becoming a biomedical engineer and the interaction formats that enabled or constrained this process provided a different vision of "humanness" in human-centered design. That is, this study described the ways in which participants actively engaged in communication design elucidating their goals, conflicts in reaching goals, the strategies enacted to overcome challenges, and the underlying normative rationale for these strategies.

Limitations

As with any research endeavor it is important to note the project's limitations. First, engagement with students who transferred out of the biomedical engineering program was a limitation. Although I was given access to all students who had recently transferred I was only limited to a select few students who were willing to participate. These students provided unique perspectives and as such any additional transfer students could have contributed to the overall richness of the data.

Second, engagement with mid-level faculty was limited simply due to the lower numbers of associate professors at this study site. The biomedical engineering school was at an interesting inflection point in their history where they were experiencing a high-level of growth resulting in a large base of assistant professors alongside the full professors who had led the organization's evolution. This left a void of associate professors. Mid-level faculty maintain different professional goals and constraints compared to their assistant and full professor counterparts that may have provided an added layer of insight to the current data set. Relatedly, I was limited to the faculty members who were willing to participate given the restricted schedules for this particular group. As such, in an ideal scenario, I would have had an opportunity to sample across faculty with various levels of experiences working with undergraduate students or those with various backgrounds. Although I was able to speak with faculty who had industry experience or came from other disciplinary backgrounds, any added diversity to the faculty set could have contributed to a more multi-faceted data set.

Similarly, the student participant group included more sophomores than juniors or seniors. Sophomore students maintained unique perspectives than their more senior counterparts. Sophomore students, for the most part, did not yet have the opportunity to participate in other learning experiences such as internships, coops, and undergraduate research. The majority of sophomore students' professional formation came from the school's curriculum and may have potentially contributed to a more deterministic view of the engineering profession versus more relativistic perspectives gained from industry or professional experiences.

Lastly, although this study was limited to only one university, one school of biomedical engineering, and only a portion of the FSA and student population—the qualitative data yielded rich data that provided a contoured and contextualized examination of engineering professional formation. The qualitative insights generated by this study serve as a springboard for future work looking to integrate design principles and professional formation inquiry. In the next section I elaborate on the theoretical implications of this study and potential future research directions.

Theoretical implications

There are a number of theoretical implications and future research opportunities related to the topics discussed in this study. First, this study's theoretical contributions showed how CaD principles or guides were applicable to macroprocesses like culture and identity formation above and beyond micro instances of talk. Principles or guides for macroprocesses also provide alternative ways of understanding organizational communication generally and innovation specifically. Innovation at the most fundamental level is about introducing something new. Communication as Design unpacks what is going on in terms of communication infrastructure and what designs presuppose about what and how communication ought to work. However, innovation occurs by not only understanding what is happening but by also overlaying other perspectives to identify and look for spaces to grow, reform, and introduce what is new.

This study showed that communication designs presupposed either an engineering scientist identity rooted in theoretical knowledge *or* an engineering practitioner rooted moreso in practical knowledge. Overlaying CaD with GPT principles identified that both ontological and epistemological premises were equally important for transcendent and inclusive professional formation. By doing so, findings highlighted spaces for innovation by challenging engineering educators to develop learning formats that were highly integrative of both theoretical and practical epistemological foundations and scientist and practitioner ontological understandings. Ultimately, this study showed how using CaD alongside other design-inspired frameworks created possibilities for understanding current designs and identifying spaces for innovation.

Second, findings indicated that there is not a monolithic BME identity but rather BME identity involves many goals, expectations, aims, and ways of "doing" biomedical engineering. The pluralism of BME identity was represented in/by the intersection of theoretical and practical knowledge with understandings of engineering scientist and engineering practitioner ontologies. Given this implication, BME identity could be parsed out further using a structurational explication of identity and identification rooted in Scott, Corman, and Cheney's (1998) structurational model of identification in the organization. The structurational model explores how identities are created in/by social interactions and implies the duality of identity and identification. Therefore, Craig et al. (1998) offers an ideal framework to parse what identities are created and called upon and in what particular situations. Unpacking the epistemological and ontological pluralism of engineering formation is particularly important to biomedical engineering. What is unique for BME is the ethical implications and nature of biomedical engineering work. The centrality of the human body and humanity in biomedical engineering increases the stakes for what BMEs should know and how they understand what it means to be and do biomedical engineering. BMEs situated too much in an engineering scientist identity construct rooted in theoretical knowledge could have serious ethical ramifications for products, devices, and services that affect everyday human lives. Similarly, BMEs situated too much in an engineering practitioner construct rooted moreso in practical knowledge could risk neglecting fundamental theoretical concepts that could equally present ethical and practical ramifications for human bodies and everyday lives.

Third, my findings suggest that an opportunity exists to explore the role situated learning experiences play in the professional formation of engineers. I argued that participants invested in and sought out situated learning experiences to overcome challenges they experienced in their professional formation. Future work could expand on these findings, by also applying GPT, and unpacking individual situated learning experiences (e.g., undergraduate research) and exploring the challenges individuals experience in the everyday talk in/by situated learning formats—and how these conflicts block ongoing discourses of professional preparation, diversity, and inclusion. Doing so could build on studies that strive to bridge communication and design theory to build formats that are human-centered and grounded in stakeholders' goals, expectations, and aims of professional formation.

Similarly, an additional theoretical implication involves the intersection of GPT and pedagogy. There is an opportunity to apply the principles of grounded practical theory to broader organizational processes above and beyond micro instances of "talk". Similar to the present research, studies could examine the expressed goals of organizational processes, conflicts that emerge in pursuit of goals, the strategies used to overcome challenges, and constitutive implications of doing so. This study indicated how grounded insights revealed theoretical concepts that can be used as design criteria for building idealized models of a particular system. In the case of the current study, a grounded approach surfaced situated learning concepts as important criteria for building idealized models of professional formation.

For engineering education in particular, the implications of contrasting professional formation goals—broad knowledge and realizing specific application—surfaced historical influences of engineering education for what it means to be an engineer and what engineers should know. Challenges with navigating breadth and depth mirrored changes in engineering education that emphasized theoretical versus practical knowledge. The shift in engineering education during the early and mid portion of the 20th century saw many engineering programs begin to shift from a practical or "hands-on" curriculum (e.g., machine shop work, surveying) to an engineering science curriculum. Engineering science in this sense included topics in "mechanics of solids, fluid mechanics, thermodynamics, heat and mass transfer, electrical theory, nature and properties of materials" (Berry, DiPlazza, & Sauer, 2003, p. 468). The shift to engineering science situated theoretical knowledge, in many ways, above and beyond practical knowledge.

The historical influences of an engineering science shift were apparent in the current findings. In particular, lecture designs supported engineering science and broad based understandings of engineering and BME, respectively. Thus, lecture formats and theoretical knowledge contributed to understandings of engineering as an "engineering scientist" (Issapour & Sheppard, 2015) above and beyond engineering practice. Engineering science epistemologies and ontologies, in and by themselves, present potential issues of students being ill-equipped with the practical and social complexities of the engineering workplace. For students to meet the increasing complex needs of doing engineering work, professional formation designs are required to maintain both engineering science and practice understandings.

Future research in engineering education can build on the approach taken in this study to uncover grounded theoretical concepts in the context of pedagogy. For instance, an opportunity exists to unpack and target lecture designs specifically and identify pedagogical concepts that can serve as design specifications. Doing so, could ultimately lead to more efficient and effective lecture design formats—designs as part of the overall trajectory of professional formation.

Future studies leveraging operationalized theoretical frameworks as design criteria can serve as an important bridge between the communication theory, engineering education, and design research. Such an endeavor could describe the relationship between the dimensionality of theoretical frameworks (e.g., content, context, community, and participation), design criteria or specifications, and identified user needs. The principles of grounded practical theory provides a normatively, pragmatic lens that provides both descriptive ("the what") and normative ("the why") organizational insight. Research such as this could represent a highly integrated and sophistical design science research enterprise. The next section builds on these theoretical implications and describes practical implications that are rooted in the current study's data and findings.

Practical implications

In the following section I describe this study's practical implications. I begin with (a) grounded practical theory implications for professional preparation, diversity, and inclusion. I then (b) discuss how engineering educators, specifically, can leverage the strategies and underlying rationale uncovered in this analysis as design criteria for building stronger professional formation processes. Next I present a (c) tentative "design roadmap" that charts short-term and long-term considerations rooted in the identified normatively, pragmatic rationale. The ultimate goal is to maintain the inherent quality of biomedical engineering–a transcendent and integrative discipline rooted in both a broad knowledge base and specific technical know-how.

Implications for professional preparation, diversity, and inclusion.

The context of this study was the professional formation of engineers and driven by the NSF's Professional Formation of Engineers (PFE) initiative. One of the key issues the PFE initiative aimed to address was the increased numbers of engineering students who were entering the professional marketplace ill-equipped to meet the demands of the engineering profession. This issue highlights the gap between what students learn in universities and what they practice upon graduation. Studies (Godfrey, 2014; Tonso, 2007, Trevelyan, 2010) indicate that many perceive engineering as solely technical, math, and theory oriented which as created a swell of incoming engineers with the lack of *socio*-technical skills to meet the demands of the marketplace—an implication of the engineering science turn of the early 20th century. A predominant engineering science view of professional engineering has also contributed to the lack of diversity and inclusion (incorporation of difference in perspectives, values, and ways of thinking and being engineers) throughout many engineering programs.

This study's findings showed how individuals of a school of biomedical engineering encountered these problems in professional formation and the remedying strategies that were used. Findings showed that situated learning experiences such as undergraduate research, lab participation, and case-intensive courses (like the school's physiology course), in complement to lectures, allowed students to develop their broad knowledge base and specific application of technical know-how. Through a community of practitioners and active participation in the meaning of technical content, students navigated through the social complexities of typical engineering tasks. This process augmented both their technical and social knowledge producing a more robust socio-technical understanding of the engineering profession. From an epistemological perspective, engineering knowledge was no longer solely technical, math, and theory oriented (i.e., engineering science) but rather a holistic discipline also involving social considerations such as environment, coordination, and empathy.

The current findings also provided important implications for diversity and inclusion in the professional formation of engineers. Community and participation were critical dimensions of the underlying philosophical rationale and for seeking out and investing in situated learning experiences. Participants on several occasions indicated how a community of diverse perspectives and ways of problem solving augmented their overall understanding of how to do biomedical engineering work. Students also participated in a community of learners and experts and contributed to and participated in the meaning of the task at hand and approaches for problem solving.

Ultimately, situated learning experiences created space for diverse ways of thinking and being. These professional formation processes expanded understandings of biomedical engineering identity and knowledge beyond the technical and theoretical to include social aspects of the discipline. Participants were able to navigate between a broad knowledge base and specific technical know-how and between engineering science and engineering practice. These experiences also allowed students to witness the impact of their work which has been shown to be a significant motivation for students from underrepresented groups (Tonso, 2014).

Situated learning experiences also leveled the field in terms of varying educational and professional preparation backgrounds. In order to overcome problems in the lecture curriculum many students relied on previous technical experiences they were provided during pre-collegiate experiences (i.e., during high school). Unfortunately, many underprivileged students were not afforded the same resources. Situated learning experiences provided a space whereby learners could engage with a community and identify the gaps and develop the skills needed to accomplish the task at hand and participate in the process of developing these skills.

Design criteria for professional formation of engineers.

Situated learning characteristics (Lave, 1988; Lave & Wenger, 1990; Brown et al., 1989; Stein, 1998) resembled the philosophical rationale uncovered in this study. These characteristics include content, context, community, and participation. These characteristics can serve as normatively, pragmatic design criteria for building professional formation interaction formats that are more aligned with the demands of the professional marketplace.

An assumption of situated learning is that learning, or knowledge, is a continuous, ongoing negotiation involving factual or procedural facts, learners, environment, experts, community members, and social interaction. Knowledge and "learning is the result of a social process encompassing ways of thinking, perceiving, problem solving, and interacting in addition to declarative and procedural knowledge" (Stein, 1998, para. 3). As such, learning is not as much retention of technical know-how but moreso an active process of learning the socio-technical complexities of professional identity, in this case the practice of biomedical engineering. Learning, or constituting professional identity, therefore is not separated by the messiness of relationships, social interaction, and environment—but rather constituted by them.

Administrative leaders for the biomedical engineering school can leverage situated learning characteristics as design criteria for building professional formation processes amenable to reconciling the dilemma of gaining a broad knowledge base while realizing specific application. Professional formation processes – i.e., learning experiences—therefore should be designed to involve: content, context, community, and participation.

Content involves specific facts and procedural knowledge (i.e., explicit knowledge) however it is the generative power of social interaction and context that provides this technical knowledge its meaning and ultimately its utility. *Context* provides the setting for the messiness of learning. Context involves all the many values, beliefs, environmental cues that influence and provide meaning for content (Lave, 1988; Lave & Wenger, 1990; Brown et al., 1989; Stein, 1998). While context provides the setting, the *community* of learners provides the social interaction whereby learners negotiate the meaning of the task at hand, relevant content, and diverse approaches for problem solving. These discourse communities engaged in the ongoing negotiation for the meanings of the task at hand and attempts at problem solving through encountering diverse views and perspectives. Finally, *participation* illuminates the active and generative ways community members can produce, maintain, and challenge disciplinary assumptions.

Agency for innovation

The current study's findings have implications for innovation. Findings identified goals of professional formation, barriers to reaching these goals, strategies used to overcoming barriers, and rationales for doing so. These dimensions of professional formation surfaced in both converging themes (e.g., most students and FSA agreed broad knowledge) and contrasting themes (e.g., some FSA felt lectures were critical while some students felt situated learning was critical). Converging and contrasting themes surfaced goals, strategies, barriers, and strategies.

Leveraging GPT and CaD perspectives findings showed the constitutive impact of communication designs such as lecture designs and situated learning designs. Findings revealed communication infrastructures maintained and reproduced by each design, infrastructures that were enabling and inhibiting for professional formation. Specifically, lecture designs maintained an infrastructure that primarily co-constructed and valued engineering science ontologies and theoretical epistemologies. Situated learning designs built on engineering science and theoretical understandings and emphasized engineering practice ontologies and practical epistemologies. However much situated learning designs provided strategies for overcoming, innovation can still occur whereby lecture designs can support practical epistemologies and situated learning designs can support and invest in more theoretical and engineering science.

These findings show how actors of a professional formation system (i.e., the school of biomedical engineering) can build and design innovative formation processes. Thus, it is important to briefly address the actors of the professional formation system (as examined in this study) and their capacity to act—in other words, the agency required for innovation. First, lecture designs could follow elements highlighted by the schools physiology course. The key actors included faculty and students and agency was given to students in form of ownership and participation. Students participated in seeking out the practical knowledge needed to apply engineering science principles. Relatedly, students were given ownership over this process and ownership over producing an outcome—a key goal of professional formation. Innovation in/by lecture designs can occur by providing more students agency to participate in their practical knowledge formation and for students to take ownership over this process. Faculty and administrators could examine current lecture curricula and identify spaces where students could participate in their own practical knowledge formation. Examination of curricula could occur across the sum of lecture curriculum within the school. Thus, all lecture curricula at the school would be intimately tied to engineering practice ontologies and epistemologies.

Situated learning designs also have space for innovation. As discussed, situated learning designs supported engineering practice ontologies and practical epistemologies. Student actors were given agency also in form of participation and ownership. Students participated in and took ownership of their practical knowledge growth. Opportunities for innovation exist and faculty actors could assume agency in identifying critical inflection points during situated learning experiences to surface the engineering science behind the practice. Faculty actors across undergraduate research, lab formats, and/or design experiences could be intentional and systematic about when to surface the engineering science behind the practice. Surfacing engineering science could come in forms such as collaborative reflections among a research group (e.g., undergraduate students, graduate students, faculty). Research groups could, on a periodic basis, reflect on the engineering science principles that were needed for a particular activity and also challenge whether they were appropriate or whether other approaches were required. Surfacing engineering science could also come about by informal "teachable moments" administered by faculty. In this scenario, faculty would be challenged to seek out (and possible document) moments during a research project, lab, or design experience they could help students understand the engineering science principles undergirding a particular engineering activity. To drive faculty agency, many of these interactions could be tied to tenure and promotion structures in order to motivate faculty participation in surfacing engineering science in practical experiences. The following design roadmap offers a starting point for developing innovative professional formation designs.

Design roadmap for implementation

Fortunately for the biomedical engineering school in this study, there are well-established learning experiences that maintain many of the situated learning characteristics. Therefore, this design roadmap presents "start" and "continue" recommendations—areas where the school should start investing and areas the school should continue current practices. Integrating design criteria at an institutional level is a significant undertaking and therefore I present both short term (1-3 years) and long term (3-5 years) design plans that can allow school administrators to slowly build, test, and iterate on ways to foreground more situated learning experiences into the curriculum.

The immediate short-term design goal would be to invest in providing undergraduate research and/or co-curricular design experiences for all students. That is, administrators should implement more directed efforts toward assuring students receive one or several undergraduate research or co-curricular design experiences. The aim would be that no student would complete the program with only having participated in course curriculum, labs, and the assigned design projects. By putting forth more intentional effort into providing these specific and additional situated learning experiences, students will have more opportunities to build on their broad knowledge base while realizing how to develop the technical know-how across many situations and for various biomedical engineering-related tasks.

Questions to consider for the short-term plans would include the coordination and scaffolding of such an endeavor. For instance, administrators would need to identify all of the current research opportunities within the school across all labs and quantify the capacity the school has for providing undergrad research. Relatedly, given capacity concerns, administrators would need to determine the ideal frequency of these experiences. Should students be in either a research opportunity or co-curricular design experience each semester or is a single participation before graduation sufficient? School administrators would also need to do conduct comprehensive due diligence examining all co-curricular design experiences currently available throughout the university. By doing so, administrators can determine all the possible options available for students and coordinate by semester which students are participating in undergrad research and/or co-curricular design experiences at any given point during the school year.

An asset of the school includes the lab experiences students are required to participate in as part of certain lecture courses. Lab experiences that provided the greatest value were those that provided maximum flexibility in what types of projects students led as well as those experiences that were heavily group-oriented. These types of lab experiences display the situated learning experiences that students sought out to overcome challenges presented in standard lecture curricula alone. As such, school administrators should continue to invest in these professional formation experiences and look for opportunities to highlight highly flexible, group-centered lab work.

The long-term design plan would involve ways for decentralizing a standard lecture curriculum across the undergraduate program and to foreground situated learning experiences as the anchor for the undergraduate experience. Such a radical programmatic change could have significant implications for a more holistic and immersive experience for students to move back and forth between gaining a broad knowledge base and realizing how to gain technical know-how. There are significant risks but also substantial upside.

Technology investments could assist in decentralizing a standard lecture curriculum at the programmatic level. School administrators could look towards online formats that could supplement the factual, declarative information required in biomedical engineering – i.e., fundamentals of physics, mathematics, thermodynamics, and so on. Students could enroll in these online curriculum programs—ala massive open online communities—and engage with this information at the pace best suited for them to retain the information. This has implications for diversity and inclusion, creating space for different types of learners from different educational levels and backgrounds. Students would have the opportunity to slow down or repeat content as needed as well as speed up or add supplemental information if need. An online curriculum would also provide more space for situated learning experiences where students can then translate the factual information they gained from their online experiences to a specific context within a community of similar aspiring practitioners.

Technology-enabled applications or technology-enabled platforms anchored in situated learning design criteria could also augment the value of situated learning experiences.

Applications or platforms could simulate biomedical engineering tasks within an online community requiring students to engage in diverse ways of thinking, approaching, and solving problems within a specific situation. The applications or platforms would need to be designed to highlight situated learning characteristics—content, context, community, and participation—and thus would involve application of technical know-how combined with an online community to participate in the meaning of the situation and diverse approaches for problem-solving.

Conclusion

This study examined the professional formation of engineers and the biomedical engineering discourse community at a school of engineering at a large, Midwestern university. I took a design stance toward the empirical examination (Aakhus, 2007) of professional formation and highlight the process by which members of this community intentionally (re)designed their discursive environment to achieve a more preferred biomedical engineering identity. Findings provided contributions for Grounded Practical Theory (Craig & Tracy, 1995), Communication as Design (CaD) (Aakhus, 2007), and Human-Centered Design (HCD) (Krippendorf, 2006). Insights also provided design criteria and design roadmaps school administrators could leverage to build stronger formats of professional formation.

REFERENCES

Aakhus, M. (2007). Communication as design. *Communication Monographs, 74*(1), 112-117. doi.org/10.1080/03637750701196383

Aakhus, M., & Jackson, S. (2005). Technology, interaction, and design. In K. Fitch & R. Sanders (Eds.), *Handbook of language and social interaction* (pp. 411-436). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Adler, P. A., & Adler, P. (1987). *Membership roles in field research*. Thousand Oaks, CA: Sage.

Albanese, M. & Mitchell, S. (1993). Problem-based learning: A review of literature on its outcomes and implementation issues. *Academic Medicine 68*(1), 52–81.

Allen, B. J. (2005). Social constructionism. In. S. May & D. K. Mumby (Eds.), *Engaging organizational community theory and research: Multiple perspectives* (pp. 35-53). Thousand Oaks, CA: Sage.

Alvesson, M., & Karreman, D. (2000). Varieties of discourse: On the study of organizations through discourse analysis. *Human Relations, 53*(9), 1125 – 1149. doi.org/10.1177/0018726700539002

Anderson, L., Krathwohl, D., & Bloom, B. (2001). *A taxonomy for learning, teaching, and assessing : a revision of Bloom's taxonomy of educational objectives.* New York: Longman.

Atman, C. J., Sheppard, S. D., Turns, J., Adams, R. S., Fleming, L. N., Stevens, R., Streveler, R. A., Smith, K. A., Miller, R. L., Leifer, L. J., Yasuhara, K., & Lund, D. (2010). *Enabling engineering student success: The final report for the Center for the Advancement of Engineering Education*. San Rafael, CA: Morgan and Claypool Publishers.

Barbour, J. B., & Gill, R. (2014). Designing communication for the day-to-day safety oversight of nuclear power plants. *Journal of Applied Communication Research, 42*(2), 168-189. doi.org/10.1080/00909882.2013.859291

Berry, F. C., DiPlazza, P. S. & Sauer, S. L. (2003). The future of electrical and computer engineering education. *IEEE Transactions on Education, 46*(4), 467 – 476. doi.org/10.1109/TE.2003.818757

Brown, J. S., Collins, A. & Duguid, S. (1989). Situated cognition and the culture of learning. *Educational Researcher, 18*(1), 32-42. doi.org/10.3102/0013189X018001032

Black, L.W., & Wiederhold, A. (2014). Discursive strategies of civil disagreement in public dialogue groups. *Journal of Applied Communication, 42*(3), 285-306. doi.org/10.1080/00909882.2014.911938

Bloom, R. (2014). Negotiating language in transnational health care: Exploring translingual literacy through grounded practical theory. *Journal of Applied Communication, 42*(3), 268-284. doi.org/10.1080/00909882.2014.911942

Bucciarelli, L. L. (1984). Reflective practice in engineering design. *Design Studies, 5*(3), 185-190. doi.org/10.1016/0142-694X(84)90012-7

Carrico, C., Winters, K., Brunhaver, S., & Matusovich, H. M. (2012). The pathways taken by early career professionals and the factors that contribute to pathway choices. *Proceedings of the 2012 American Society for Engineering Education Annual Conference & Exposition*, San Antonio, TX.

Colliver, J. A. (2000), Effectiveness of problem-based learning curricula: Research and theory. *Academic Medicine, 75*(3), 259-266.

Cooren, F. (2015). *Organizational discourse: Communication and constitution*. Cambridge, UK: Polity Press.

Cooper, P. J. (1981). Speech communication for the classroom teacher. Dubuque, IO: Gorsuch Scarisbrick.

Craig, R. T., & Tracy, K. (1995). Grounded practical theory and the case of intellectual discussion. *Communication Theory, 5*(3), 248-272. doi.org/10.1111/j.1468-2885.1995.tb00108.x

Cross, N. (2006). *Designerly ways of knowing*. London, UK: Springer.

Diaz-Garcia, C., Gonzalez-Moreno, A., & Saez-Martinez, F.J. (2013). Gender diversity within R&D teams: Its impact on radicalness of innovation. *Innovation: Organization & Management, 15*(2), 149-160. doi.org/10.5172/impp.2013.15.2.149

Dimock, A. (2010). Styles of rejection in local public argument on Iraq. Argumentation, 24, 423–452. doi:10.1007/s10503-009-9175-6

Drew, P., Chatwin, J., & Collins, S. (2001). Conversation analysis: A method for research into interactions between patients and health-care professionals. Health Expectations: An International Journal of Public Participation in Health Care and Health Policy, 4(1), 58–70. doi:10.1046/j.1369-6513.2001.00125.x

Dunlap, J. C. (2005). Problem-based learning and self-efficacy: How a capstone course prepares students for a profession. *Educational Technology Research and Development, 53*(1), 65-83. doi.org/10.1007/BF02504858

Eddington, S., Torres, D. H., Zoltowski, C. B, Joshi, R., Brightman, A. O., Buzzanell, P. M. (2018). Diversity and inclusion in engineering: Students' perceptions of learning and engaging with difference. Proceedings of the American Society for Engineering Education (ASEE). Salt Lake City, UT: ASEE.

EPICS. (2009). *EPICS design process*. EPICS Purdue University, West Lafayette, IN. Retrieved from https://engineering.purdue.edu/EPICS

Fairhurst, G. T., & Putnam, L. (2004). Organizations as discursive constructions. *Communication Theory, 14*(1), 5-26. doi.org/10.1111/j.1468-2885.2004.tb00301.x

Froyd, J. E., Wankat, P. C., & Smith, K. A. (2012). Five major shifts in 100 years of engineering education. *Proceedings of the IEEE,* 100, 1344-1360. doi.org/10.1109/JPROC.2012.2190167

Friedman, H.H., Weiser Friedman, L., & Leverton, C. (2014). Increase diversity to boost creativity and enhance problem solving. *Psychosociological Issues in Human Resource Management, 4*(2), 7-33.

Gavalcova, T. (2008). On strategies contributing to active learning. *Teaching Mathematics and its Applications: An International Journal of the IMA, 27*(3), 116-122. doi.org/10.1093/teamat/hrn013

Gergen, K. J. (1985). The social constructionist movement in modern psychology. *American Psychologist, 40*(3), 266-275.

Giddens. A. (1990). *The consequences of modernity*. Cambridge, UK: Polity Press

Glaser, B. G., & Strauss, A. L. (1967). *The discovery of grounded theory: Strategies for qualitative research*. Chicago, IL: Aldine.

Godfrey, E. (2015). Understanding disciplinary cultures: The first step to cultural change. In A. Johri & B. Olds (Eds.), *Cambridge Handbook of Engineering Education Research* (pp. 437-456). New York, NY: Cambridge University Press.

Godfrey, E., & Parker, L. (2010). Mapping the cultural landscape in engineering education. *Journal of Engineering Education*, *99*(1), 5–22. doi.org/10.1002/j.2168-9830.2010.tb01038.x

Gold, R. L. (1958). Roles in sociological field observations. *Social Forces, 36*(3), 217-223. doi.org/10.2307/2573808

Grzywacz, J.G., & Carlson, D.S. (2007). Conceptualizing work-family balance: Implications for practice and research. *Advances in Developing Human Resources, 9*(4), 455-471. doi.org/10.1177/1523422307305487

Guttman, N. (2007). Bringing the mountain to the public: Dilemmas and contradictions in the procedures of public deliberation initiatives that aim to get “ordinary citizens” to deliberate policy issues. *Communication Theory, 17*(4), 411-438. doi.org/10.1111/j.1468-2885.2007.00305.x

Harrison, T. R. (2014). Enhancing communication intervention and evaluation through communication design. *Journal of Applied Communication Research, 42*(2), 135-149. doi.org/10.1080/00909882.2013.825047

Hayden, C. & Jenkins, C. (2014). 'Troubled families' programme in England: 'wicked problems' and policy-based evidence. *Policy Studies, 35*(6), 631-649. doi.org/10.1080/01442872.2014.971732

Head, B.W., & Alford, J. (2015). Wicked problems: Implications for public policy and management. *Administration & Society, 47*(6), 711-739. doi.org/10.1177/0095399713481601

Heritage, J., & Maynard, D. (2006). *Communication in medical care: Interaction between physicians and patients*. Cambridge: Cambridge University Press.

IDEO. (2019). IDEO design kit. Retrieved from www.designkit.org.

IDEO Field Guide. (2015). *The field guide to human-centered design*. Chicago: IDEO.org. Retrieved from www.ideo.org.

Issapour, M., & Sheppard, K. (2015). Evolution of American engineering education. *Conference for Industry and Education Collaboration*. Palm Springs, CA: ASEE.

Jacobs, S. (1994). Language and interpersonal communication. In M. Knapp & G. Miller (Eds.), *Handbook of interpersonal communication* (pp. 199-228). Newbury Park, CA: Sage.

Jackson, S. (1998). Disputation by design. *Argumentation*, 12, 183-198. doi.org/10.1023/A:1007743830491

Jackson, S. (2002). Designing argumentation protocols for the classroom. In F. H. van Eemeren (Ed.), *Advances in pragma-dialectics* (pp. 105-120). Amsterdam, The Netherlands: SICSAT.

Jackson, S., & Aakhus, M. (2014). Becoming more reflective about the role of design in communication. *Journal of Applied Communication Research, 42*(2), 125-134. doi.org/10.1080/00909882.2014.882009

Jones, J. C. (1992). *Design methods* (2nd ed.). New York, NY: Van Nostrand Reinhold.

Joshi, R., Zoltowski, C. B., Brightman, A. O., Eddington, S., Buzzanell, P. M., & Torres, D. H. (2018). Evaluating the impact of design sessions on participants' perceptions of diversity and inclusion in the professional formation of biomedical engineers. *Proceedings of the American Society for Engineering Education (ASEE).* Salt Lake City, UT: ASEE.

Koening, C. J., Wingard, L. M., Sabee, C., Olsher, D., & Vandergriff, I. (2014). Managing patient-centered communication across the Type 2 Diabetes illness trajectory: A grounded practical theory of interactional sensitivity. *Journal of Applied Communication Research, 42(3),* 244-267. doi.org/10.1080/00909882.2014.911943

Krippendorf, K. (2006). *The semantic turn: A new foundation for design*. Boca Raton, FL: Taylor & Francis group.

Krippendorf, K. (2016). Design. In K.B. Jensen, E.W. Rothenbuhler, J.D. Pooley, & R.T. Craig (Eds.), *The international encyclopedia of communication theory and philosophy* (pp. 1-12). Hoboken, NJ: Wiley. doi.org/10.1002/9781118766804.wbiect264

Kuhn. T. (2008). A communicative theory of the firm: Developing an alternative perspective on intra-organizational power and stakeholder relationships. *Organization Studies, 29*(8-9), 1227-1254. doi.org/10.1177/0170840608094778

Kuhn, T., & Nelson, N. (2002). Reengineering identity: A case study of multiplicity and duality in organizational identification. *Management Communication Quarterly, 16*(1), 5-38. doi.org/10.1177/0893318902161001

Leeds-Hurwitz, W. (1995). *Social approaches to communication* (Eds.). New York: Guilford Press.

Larson, G. S., & Pepper, G. L. (2003) Strategies for managing multiple organizational identifications: A case of competing identities. *Management Communication Quarterly, 16*(4), 528-557. doi.org/10.1177/0893318903251626

Lave, J. (1988). Cognition in Practice: Mind, mathematics, and culture in everyday life. Cambridge, UK: Cambridge University Press.

Lave, J., & Wenger, E. (1990). *Situated learning: Legitimate peripheral participation*. Cambridge, UK: Cambridge University Press.

Leavy, P. (2011). *Essentials of Transdisciplinary Research: Using Problem-Centered Methodologies*. 1st Edition. New York: Routledge. doi.org/10.4324/9781315429137

Leonardi, P. M. (2008). Indeterminacy and the discourse of inevitability in international technology management. *The Academy of Management Review, 33*(4), 975-984. doi.org/10.5465/amr.2008.34422017

Leonardi, P. M. (2010). From road to lab to math: The co-evolution of technological, regulatory, and organizational innovations in automotive crash testing. *Social Studies of Science, 40*(2), 243-274. doi.org/10.1177/0306312709346079

Lewis, S., Gambles, R., & Rapoport, R. (2007). The constraints of a 'work-life balance' approach: An international perspective. *The International Journal of Human Resource Management, 18*(3), 360-373. 10.1080/09585190601165577

Lindlof, T. R., & Taylor, B. C. (2011). *Qualitative research methods* (3rd ed.). Thousand Oaks, CA: Sage.

Mael, F., & Ashforth, B. E. (1992). Alumni and their alma mater: A partial test of the reformulated model of organizational identification. *Journal of Organizational Behavior, 13*,(2), 103-123. doi.org/10.1002/job.4030130202

Maffin, D. (1998). Engineering design models: Context, theory and practice. *Journal of Engineering Design, 9*(4), 315-327. *doi.org/10.1080/095448298261462*

Mallin, I. (2017). Lecture and active learning as a dialectical tension. *Communication Education, 66*(2), 242-243. dx.doi.org/10.1080/03634523.2016.1275720

Maykut, P., & Morehouse, R. (2001). *Beginning qualitative research: A philosophic and practical guide* (pp. 126-149). London, UK: Routledge.

Mazer, J. P. & Hess, J. A. (2017). What is the place of lecture in higher education? *Communication Education, 66*(2), 236-237. doi.org/10.1080/03634523.2017.1287411

McMillan, H.S., Morris, M.L. & Atchley, E.K. (2010). Constructs of the work/life interface: A synthesis of the literature and introduction of the concept of work/life harmony. *Human Resource Development Review, 10*(1), 6-25. doi.org/10.1177/1534484310384958

McNair, T. B. & Albertine, S. (2012). Seeking high-quality, high-impact learning: The imperative of faculty development and curricular intentionality. *Peer Review, 14*(3), 4-5.

Merriam-Webster. (2017). *Technology*. Retrieved from https://www.merriam-webster.com/dictionary/technology

Merriam-Webster. (2018). *Protocol*. Retrieved from https://www.merriam-webster.com/dictionary/protocol

Merriam-Webster. (2019). *Presuppose*. Retrieved from https://www.merriam-webster.com/dictionary/presuppose

Meyer, K.R., & Hunt, S. K. (2017). The lost art of lecturing: cultivating student listening and notetaking. *Communication Education, 66*(2), 239-241. dx.doi.org/10.1080/03634523.2016.1275719

Nelson, H. G., & Stolterman, E. (2012). *The design way: Intentional change in an unpredictable world* (2nd ed.). Cambridge, MA: MIT Press.

National Science Foundation (NSF). (2015). Professional Formation of Engineers (PFE: RIEF) Research Initiation in Engineering Formation Retrieved from https://www.nsf.gov/pubs/2015/nsf15539/nsf15539.htm

Oxford Dictionary. (2019). *Interactivity*. Retrieved from https://en.oxforddictionaries.com/definition/interactivity

Zoltowski, C.B., Buzzanell, P.M., Brightman, A.O., Torres, D. Eddington, S. M. Joshi, R. (2017). Understanding the professional formation of engineers through the lens of design thinking: Unpacking the wicked problem of diversity and inclusion. *Proceedings of the American Society for Engineering Education (ASEE).* Columbus, OH: ASEE.

Zimmerman, B. J. (1989). A social cognitive view of self-regulated academic learning. *Journal of Educational Psychology, 81*(3), 329-339. http://dx.doi.org/10.1037/0022-0663.81.3.329

Peffers, K., Tuunanen, T., Rothenberger, M.A., & Chatterjee, S. (2014). A design science research methodology for information systems research. *Journal of Management Information Systems, 24*(3), 45-77. doi.org/10.2753/MIS0742-1222240302

Phillips, K. How diversity makes us smarter. *Scientific American*. Retrieved from https://www.scientificamerican.com/article/how-diversity-makes-us-smarter/

Putnam, L. L., & Powers, S.R. Contradictions and dialectics as keys to conflict transformation. In P. M. Kellet & T.G. Matyok (Eds.), *Transforming conflict through communication in personal, family, and working relationships* (pp. 3-22). New York: Lexington Books.

Putnam, L. L., Fairhurst, G. T., & Banghart, S. (2016). Contradictions, dialectics, and paradoxes in organizations: A constitutive approach. *The Academy of Management Annals, 10*(1), 65-171. doi.org/10.1080/19416520.2016.1162421

Putnam, L. L., Phillips, N., & Chapman, P. (1996). Metaphors of communication and organization. In S. R. Clegg, C. Hardy, & W. R. Nord (Eds.), *Handbook of organization studies* (pp. 375-408). Thousand Oaks, CA, US: Sage Publications, Inc.

Radcliffe, D. (2006). Shaping the discipline of engineering education. *Journal of Engineering Education*, *95*(4), 263–264. doi.org/10.1002/j.2168-9830.2006.tb00901.x

Rittel, H. W., & Webber, M. M. (1973). Dilemmas in a general theory of planning. *Policy Sciences, 4*(2), 155-169. doi.org/10.1007/BF01405730

Rittel, H. W. J., & Webber, M. M. (1984). Planning problems are wicked problems. In N. Cross (Ed.), *Developments in design methodology* (pp. 135-144). New York, NY: John Wiley & Sons.

Robinson, J. D. (2011). Conversation analysis and health communication. In T. Thompson, A. Dorsey, K. Miller, & R. Parrott (Eds.), *Handbook of health communication* (2nd ed.) pp. 501–518. Mahwah, NJ: Lawrence Erlbaum.

Schön, D. A. (1983). The reflective practitioner: How professionals think in action. New York, NY: Basic Books.

Schön, D. A. (1984). Design: A process of enquiry, experimentation and research. *Design Studies, 5*(3), 130-131.

Scott, C.R., Corman, S., & Cheney, G. (1998). Development of a structurational model of identification in the organization. *Communication Theory, 8*(3), 298-336. doi.org/10.1111/j.1468-2885.1998.tb00223.x

Shaffer, M.A., Joplin, J.R.W. & Hsu, Y. (2011). Expanding the boundaries of work-family research: A review and agenda for future research. *International Journal of Cross Cultural Management, 11*(2), 221-268. doi.org/10.1177/1470595811398800

Sheppard, S., Gilmartin, S., Chen, H.L., Donaldson, K., Lichtenstein, G., Eris, Ö., Lande, M., & Toye, G. (2010). *Exploring the engineering student experience: Findings from the academic pathways of people learning engineering survey (APPLES) (TR-10-01)*. Seattle, WA: Center for the Advancement for Engineering Education.

Shigley, J. E., Mischke, C. R., & Budynas, R. G. (2004). *Mechanical engineering design* (7th ed.) New York, NY: McGraw-Hill.

Simon, H. A. (1969). *The sciences of the artificial*. Cambridge, MA: MIT Press.

Spicker, P. (2016). Poverty as a wicked problem. *CROP: Mobilizing critical research for preventing and eradicating poverty*. Retrieved from https://www.crop.org/CROPNewsEvents/Poverty-as-a-wicked-problem.aspx

Sprain, L., Carcasson, M., & Merolla, A. J. (2014). *Utilizing "on tap" experts in deliberative forums: Implications for design, 42*(2), 150-167. doi:10.1080/03634523.2016.1275723

Stearns, S. (2017). What is the place of lecture in student learning today? *Communication Education, 66*(2), 243-245. doi.org/10.1080/03634523.2016.1275723

Stein, D. (1998). Situated learning in adult education. *ERIC Digest, 3*. Retrieved from https://www.ericdigests.org/1998-3/adult-education.html

Stevens, R., Johri, A., & O'Connor, K. (2014). Professional engineering work. In A. Johri & B. Olds (Eds.), *Cambridge handbook of engineering education research* (pp. 119-137). New York, NY: Cambridge University Press.

Thompson, J.A., & Bunderson, J.S. (2001). Work-nonwork conflict and the phenomenology of time: Beyond the balance metaphor. *Work and Occupations, 28*(1), 17-39. doi.org/10.1177/0730888401028001003

Tracy, K. (2005). Reconstructing communicative practice: Action-implicative discourse analysis. In K. Fitch & R. Sanders (Eds.), *Handbook of language and social interaction* (pp. 301-324). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Tracy, S.J. (2007). Taking the plunge: A contextual approach to problem-based research. *Communication Monographs, 74*(1), 106-11. doi.org/10.1080/03637750701196862

Tracy, K., & Craig, R.T. (2010). Studying interaction in order to cultivate communicative practices: Action-implicative discourse analysis. In J. Streeck (Ed.), *New adventures in language and interaction* (pp. 145–165). Amsterdam, The Netherlands: John Benjamins.

Trethewey, A. (2000). Cultured bodies: Communication as constitutive of culture and embodied identity. *The Electronic Journal of Communication, 10*(1/2). Retrieved from www.cios.org/getfile/TRETHE_V10N1200

Tonso, K. L. (2007). *On the outskirts of engineering: Learning identity, gender, and power via engineering practice*. Rotterdam, The Netherlands: Sense.

Tonso, K. L. (2014). Engineering identity. In A. Johri & B. Olds (Eds.), *Cambridge handbook of engineering education research* (pp. 267-282). New York, NY: Cambridge University Press.

Trevelyan, J. (2007). Technical coordination in engineering practice. *Journal of Engineering Education*, *96*(3), 191-204. doi.org/10.1002/j.2168-9830.2007.tb00929.x

Trevelyan, J. (2010). Reconstructing engineering from practice. *Engineering Studies, 2*(3), 175-196. doi.org/10.1080/19378629.2010.520135

University BME. (2019). School of Biomedical Engineering site. Retrieved from https://School of Biomedical Engineering

University Data Reporting. (2017). Reports. Retrieved from https://University Data Reporting

University IE. (2018). School of Industrial Engineering site. Retrieved from https://University IE site

University Initiative. (2019). University's 150 year anniversary site. Retrieved from https://University Initiative

Waldeck, J.H., & Weimer, M. (2017). Sound decision making about the lecture's role in the college classroom. *Communication Education, 66*(2), 247-250. dx.doi.org/10.1080/03634523.2016.1275721

Walker, A.E., Leary, H., Hmelo-Silver, C.E., & Ertmer, P.A. (2015). *Essential Readings in Problem-based Learning*. West Lafayette, IN. Purdue University Press.

Walters, R. J. (1986). Informed, well-ordered and reflective: design inquiry as action research. *Design studies, 7*(1), 2-13. doi.org/10.1016/0142-694X(86)90002-5Get

White, P. J., Larson, I., Styles, K., Yuriev, E., Evans, D. R., Rangachari, P. K.,…Naidu, S. (2016). Adopting an active learning approach to teaching in a research-intensive higher education context transformed staff teaching attitudes and behaviours. *Higher Education Research & Development, 35*(3), 619–633. doi:10.1080/07294360.2015.1107887

Zoltowski, C. B., & Oakes, W. C. (2014). Learning by doing: Reflections of the EPICS Program. *International Journal for Service Learning in Engineering, 9*(1), 1-32. doi.org/10.24908/ijsle.v0i0.5540

APPENDIX A: SEMI-STUCTURED INTERVIEW PROTOCOLS

Student interview protocol

General questions

- Just to start, if you don't mind telling me a little bit about myself
- Why did you decide to come to Purdue?
- What about engineering appealed to you?
- What about BME appealed to you?
- What did you think about engineering was when you arrived?
    - Was it the same?
    - Was it different?
    - How was different?
    - Describe to me when you realized it was different.

Views on what it means to be an engineer

- What does it mean to you to be a BME engineer?
- What are some activities that BME engineers typically do?
    - In Academia?
    - In industry?
- What are some attributes and/or qualities inherent to being a/an BME engineer?
    - Different for academia and industry?
- What would you say determines if someone is a "successful" BME engineer?
- What would you say is a distinguishing point of pride of being a BME engineer?
- What kinds of things do you think you'll be doing in your profession – what sorts of activities?
- What kinds of things do you think BME engineers *should* be doing or continue to do?

Views on what engineers should know

- In your own words, what are some of the fundamental things BME engineers *should* know?
    - Is it different for academia and industry?
- What areas of knowledge do you feel is emphasized at your school?
    - What are some examples that make you feel this way?

Views on how engineering is taught

- How would you say students in BME at Purdue learn the skills and knowledge to become a successful BME engineer?
    - What sorts of activities are most prominent in teaching?

- How *should* BME engineering be taught?
    - Why so?
- What are one or two classes you think are exemplars of an BME course?
  - Walk me through the typical day in one of these classes.
  - What are the student-to-student interactions like?
  - What are the student-to-faculty interactions like?
  - How is information presented?
  - How is knowledge or learning assessed? (e.g., projects, exams, homework, etc.)

Purdue Disciplinary Culture

- Walk me through a through a typical academic day for you – beginning whenever it is you feel your start the academic day.
    - What are some of the first things you do? How do these activities change throughout the day?
    - Who do you normally encounter or interact with?
    - When do you normally interact with them?
    - Where do you normally go during a typical academic day?
- Let's say this is my first week as a BME student and I come to you for advice on how to best fit in. As a member of [discipline] engineering, what would you tell me I need to do or attributes I need to demonstrate to be a "good" member/student of this school?
- How would you describe the culture of BME at Purdue
  - How does this compare to BME outside of Purdue?
- What are some obstacles you face that get in the way from becoming a BME engineer?
    - These could be formal things like course structure, curriculum, graduation requirements, etc. Or they can informal things like, interactions with peers, faculty relationships, exposure to professional development activities (e.g., design opportunities, internships, etc.)
- What are some of the "unwritten rules" of your BME?
- What *should* the BME culture be like here at Purdue?

Views on acceptance of difference and diversity and inclusion [Godfrey dimension – Acceptance of Difference

- How would you define diversity and inclusion?
- How have you learned about diversity and inclusion?
    - Where do you hear it?
- To what degree do you believe your school is inclusive?
  - What makes you feel this way?
- To what degree is diversity valued here in BME?
  - What makes you feel this way?
- What are some of the formal activities related to diversity and inclusion you see occurring?
- What are some of the informal activities you see happening (i.e., interactions among peers, etc.)?

- What formal or informal activities related to diversity and inclusion do you think *should* be happening?
- What role do you think diversity and inclusion has in preparing you as a BME engineer?

Views on relationships [Godfrey dimension – Relationships]

- What are three adjectives that describe the **student to student relationships** in BME?
  - Why did you choose these?
  - What examples do you have that make you feel this way?
  - Are there any recent interactions that stand out that were “out of the norm”?
  - How do you think these relationships *should* look like?
- What are three adjectives that describe the **faculty to faculty relationships** in BME?
  - Why did you choose these?
  - What examples do you have that make you feel this way?
  - Are there any recent interactions that stand out that were “out of the norm”?
  - How do you think these relationships *should* look like?
- What are three adjectives that describe the **student to faculty relationships** in BME?
  - Why did you choose these?
  - What examples do you have that make you feel this way?
  - Are there any recent interactions that stand out that were “out of the norm”?
  - How do you think these relationships *should* look like?

Personal narrative:

- If you don’t mind, please share with me three challenges you experienced while becoming an engineer.

Final question: Is there anything else that you think is important for me to know about [discipline] that I have not asked about?

Thank you for your time!

FSA interview protocol

Introduction:

- Just to start, if you don't mind telling me a little bit about myself
- Tell me about the circumstances that led you to Purdue
- What about working in engineering appealed to you?
- What about working in BME appealed to you?

Views on what it means to be a BME engineering

- What does it mean to you to be a BME engineer?
- What are some activities that BME engineers typically do?
    - Is it different for academia and industry?
- What are some attributes and/or qualities inherent to being a/an BME engineer?
    - Is it different for academia and industry?
- What would you say determines if someone is a "successful" BME engineer?
- What would you say is a distinguishing point of pride of being a BME engineer?
- What kinds of things do you think BME engineers *should* be doing or continue to do?

Views on what engineers should know

- In your own words, what are some of the fundamental things BME engineers *should* know?
    - Is it different for academia and industry?
- What areas of knowledge do you feel is emphasized at your school, especially for undergraduates
    - What are some examples that make you feel this way?

How do students come to know about BME?

- How would you say students in BME at Purdue learn the skills and knowledge needed to become a successful BME engineer?
- What sorts of activities are most prominent in teaching?
- How *should* BME engineering be taught?
- What are one or two classes you think are exemplars of an BME course?
    - Walk me through the typical day in one of these classes.
    - What are the student-to-student interactions like?
    - What are the student-to-faculty interactions like?
    - How is information presented?
    - How is knowledge or learning assessed? (e.g., projects, exams, homework, etc.)
- How do you think these activities prepare students for industry? For academia?

Purdue Disciplinary Culture

- Let's say this is my first week in a new [role] here in the school and I come to you for advice on how to best fit in. As a member of BME engineering, what would you tell me I need to do or attributes I need to demonstrate to be a "good" member of this school?
- How would you describe the culture of BME at Purdue
    - How does this compare to BME outside of Purdue?
- What are some of the "unwritten rules" of your BME?
- What *should* the BME culture be like here at Purdue?

Views on acceptance of difference and diversity and inclusion [

- How would you define diversity and inclusion?
- To what degree do you believe your school BME is inclusive?
    - What makes you feel this way?
- To what degree is diversity valued here in BME?
    - What makes you feel this way?
- What are some of the formal activities related to diversity and inclusion you see occurring?
- What are some of the informal activities you see happening (i.e., interactions among peers, etc.)?
- What formal or informal activities related to diversity and inclusion do you think *should* be happening?

Views on relationships

- What are three adjectives that describe the **student to student relationships** in BME?
    - Why did you choose these?
    - What examples do you have that make you feel this way?
    - Are there any recent interactions that stand out that were "out of the norm"?
    - How do you think these relationships *should* look like?
- What are three adjectives that describe the **faculty to faculty relationships** in BME?
    - Why did you choose these?
    - What examples do you have that make you feel this way?
    - Are there any recent interactions that stand out that were "out of the norm"?
    - How do you think these relationships *should* look like?
- What are three adjectives that describe the **student to faculty relationships** in BME?
    - Why did you choose these?
    - What examples do you have that make you feel this way?
    - Are there any recent interactions that stand out that were "out of the norm"?
    - How do you think these relationships *should* look like?

Views on school's relationships to external

- How would you describe the relationship between your school and Purdue?
- How would you describe the relationship between your school and industry?

Personal narrative:

- If you don't mind, please share with me three challenges you experienced while becoming an engineer.

Final question: Is there anything else that you think is important for me to know about [discipline] that I have not asked about?

Thank you for your time!

APPENDIX B: IRB APPROVAL FOR INTERVIEWS

Purdue IRB Protocol #: 1604017518 - Expires on: 27-APR-2017

RESEARCH PARTICIPANT CONSENT FORM – Faculty and staff interviews
Understanding the Professional Formation of Engineers

Dr. Carla B. Zoltowski
School of Electrical & Computer Engineering
Dr. Patrice M. Buzzanell
Brian Lamb School of Communication
Susan Bulkeley Butler Center for Leadership Excellence
Dr. Andrew O. Brightman
Weldon School of Biomedical Engineering
Purdue University

What is the purpose of this study?

Thank you for agreeing to take part in this research effort to study the professional formation of engineers among undergraduate engineering students. We are also interested in how diversity and inclusion functions in the professional formation of engineering students.

What will I do if I choose to be in this study?

For this study you will be asked to participate in semi-structured interviews and possibly again in two years. These questions are mostly comprised of questions and prompts related to various aspects of the professional formation of engineers as well as to diversity and inclusion. There is also the possibility of participating in a follow up online survey and additional follow up interviews. The interview sessions will be audio recorded for transcription purposes only.

How long will I be in the study?

The estimated time required to complete each interview is 60 minutes, or up to 120 minutes total for both interviews.

What are the possible risks or discomforts?

You understand that the risks associated with participating in this study are no more than what you would encounter in everyday life.

Are there any potential benefits?

You understand that participating in this study involves no direct benefits to you.

Will information about me and my participation be kept confidential?

You understand that if you participate in this study we will use a randomly generated pseudonym as a way to identify your responses for data analysis. E-mail addresses will also be collected and used for potentially inviting you to participate in a follow-up interview. You also understand that, although rare, possibilities for a breach in confidentiality exist. However, there are safeguards in place to minimize

Purdue IRB Protocol #: 1604017518 - Expires on: 27-APR-2017

the possibilities of any such breach. Contact information will be stored in a secure database accessible only by the principal investigators and research personnel. Audio recordings will also be stored in a secure database accessible only by the principal investigators and research personnel. Once all recordings have been transcribed and all participant information have been anonymized (identifying information removed), all audio recordings will be immediately destroyed. The project's research records may be reviewed by departments at Purdue University responsible for regulatory and research oversight as well as sponsoring agencies.

What are my rights if I take part in this study?

Your participation in this study is voluntary. You may choose not to participate or, if you agree to participate, you can withdraw your participation at any time without penalty or loss of benefits to which you are otherwise entitled.

Who can I contact if I have questions about the study?

If you have questions, comments or concerns about this research project, you can talk to one of the researchers. Please contact Dr. Carla Zoltowski at 765-494-2382 or cbz@purdue.edu., Dr. Patrice Buzzanell at (765) 494-3317 or buzzanel@purdue.edu, or Dr. Andrew Brightman at (765) 496-3537 or aob@purdue.edu.

If you have questions about your rights while taking part in the study or have concerns about the treatment of research participants, please call the Human Research Protection Program at (765) 494-5942, email (irb@purdue.edu) or write to:

Human Research Protection Program - Purdue University
Ernest C. Young Hall, Room 1032
155 S. Grant St.,
West Lafayette, IN 47907-2114

Documentation of Informed Consent

I have had the opportunity to read this consent form and have the research study explained. I have had the opportunity to ask questions about the research study, and my questions have been answered. I am prepared to participate in the research study described above. I will be offered a copy of this consent form after I sign it.

________________________________ ____________________
Participant's Signature Date

____
Participant's Name

________________________________ ____________________
Researcher's Signature Date