AN INQUIRY INTO THE NATURE AND CAUSES OF THE STATE OF U.S. ENGINEERING ETHICS EDUCATION

by

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ABSTRACT

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There is a large variation in the quantity and quality of ethics that U.S. engineering students learn. Why is there so much room for improving the state of engineering ethics education in the United States? Recognizing the interplay between individual agency, structural factors, and historical contingency, this dissertation is a three-part approach to answering that question – I present three distinct, mutually informative threads for studying engineering ethics education from different angles. The first thread is an historical approach. The second thread is an empirical study of the mental models that faculty members have regarding engineering ethics education. The third thread applies theoretical constructs from political science and economics to analyze structural factors impinging on engineering ethics education.

From the studies, first we see that trailblazers of engineering ethics developed the new knowledge required of this emerging field through interpersonal relationships; they leveraged existing organizations and built new institutional mechanisms for sharing knowledge and creating a community of scholars and an engineering ethics curriculum; they utilized resources from supportive colleagues and administrators to corporate, governmental, and nongovernmental funding that legitimated their work. Their efforts ultimately created pedagogical materials, prevalent ideas, publication outlets, meetings, and foundations that not only contributed to the current state of U.S. engineering ethics education but also the launching point for future generations to build upon and continue developing that state. Second, mapping the mental models of engineering ethics education among engineering faculty members provided a typology for analyzing the state of engineering ethics education and places where one can expect to find variation, deepening our understanding of the state of engineering ethics education. Third, outlining a theory of the political economy of engineering education highlighted factors that could be influencing curricular and pedagogical decisions in engineering departments. Furthermore, I

supplemented the outlined theoretical phenomena with data from the mental models interviews in order to provide a proof of concept and relevant grounding for the phenomena.

In sum, faculty members make decisions based on their mental models. Structural factors shape the broader environment and institutions in which those faculty members operate. Those structures and institutions change over time, leading to the current state of engineering ethics education. Having all three pieces has provided a more complete understanding of the state of U.S. engineering ethics education.

Ultimately, my dissertation accomplishes multiple goals. First, I have provided additional evidence for understanding and explaining the qualitative and quantitative discrepancies of engineering ethics coverage in U.S. undergraduate engineering education at multiple levels of analysis. Second, I have amassed evidence that can inform future research efforts. Third, I have demonstrated the use of certain theories and methods infrequently employed in engineering education research. Finally, I have outlined potential new avenues for interdisciplinary research, especially at the nexus of political economy, education, engineering, and society.

CHAPTER 1. INTRODUCTION TO UNDERSTANDING THE STATE OF U.S. ENGINEERING ETHICS EDUCATION

Preface

There is a large variation in the quantity and quality of ethics that U.S. engineering students learn. Why is there so much room for improving the state of engineering ethics education in the United States? This dissertation is a three-part approach to answer that question. Recognizing the interplay between individual agency, structural factors, and historical contingency, there are three distinct, mutually informative threads for studying engineering ethics education from different angles. The first is a historical approach. The second is a contemporary empirical study of the mental models that faculty members have regarding engineering ethics education. The third applies theoretical constructs from political science and economics to analyze structural factors impinging on engineering ethics education. Ultimately, my dissertation will attempt to accomplish multiple goals. First, I will provide additional evidence for understanding and explaining the qualitative and quantitative discrepancies of engineering ethics coverage in U.S. undergraduate engineering education at multiple levels of analysis. Second, I will amass evidence that can inform future research efforts. Third, I will demonstrate the use of certain theories and methods infrequently employed in engineering education research. Finally, I will outline potential new avenues for interdisciplinary research, especially at the nexus of political economy, education, engineering, and society.

Introduction

This dissertation is about a simple, peculiar observation. In particular, how can we understand the discrepancy between an expectation and a reality? The naïve expectation in question: engineers learn about ethical decision-making in their undergraduate programs. The typical reality: some engineers do learn about engineering ethics, but historically undergraduate engineering ethics education has been deemed inadequate in both quantity and quality (Benya, Fletcher, Hollander, & NAE, 2013, p. 2; NAE, 2005, p. 87; National Research Council, 1985, p. 120) – or, more positively, there is still ample room to improve the state of engineering ethics education. Why is there still so much room for change?

The following sections frame this problem between expectations and reality more concretely. I will then review the research questions that I answered through three separate yet mutually informative projects that all revolve around this central theme of the state of U.S. engineering ethics education. I conclude this chapter with some limitations that accompanied the expansive approach I have taken for this dissertation.

Engineering and Ethics

In some views and contexts, such as those concerning the Grand Challenges of Engineering, engineers are working on problems that "are relevant to everyone in every country. In fact, some of them bear on the very survival of society" (NAE, 2016a). The scale and scope of these projects should not pass unappreciated for *at least* two reasons. First, there is the sheer number of people whose lives engineers can affect. Ideally, these effects are benign, auspicious, and Pareto optimal – that is, they make people better off without making anyone else worse off (Sen, 1970). Realistically, however, tradeoffs exist, and underdeveloped considerations can lead to malign outcomes of an unethical nature, to say the least. Second, a modern problem's complexity may increase proportionally with the problem's size, and this complexity creates its own obfuscating issues. As a participant in the Grand Challenges forum observed, the system's complexity has come to overwhelm a single person's capacity to fully comprehend the system, and "in such an environment, it's easy for ethics to get lost" (NAE, 2016a). That is, when the stakes associated with engineering problems grow to unprecedented proportions, the imperative for ethical engineering practices grows as well (Benya et al., 2013; Stephan, 2001).

Engineering problems have become more expansive, affecting larger populations, and some have become more ethically knotty as well, such as with geoengineering (Hamilton, 2014) and domestic surveillance technologies (Stanley & Steinhardt, 2014). Furthermore, this phenomenon is increasingly pervasive. Take academia, for example, where "increasing complexity and competitiveness in research environments, the prevalence of interdisciplinary and international involvement in research projects, and the close coupling of commerce and academia have created an ethically challenging environment for young scientists and engineers" (Hollander, Arenberg, & National Academy of Engineering, 2009, p. 1). The same general phenomenon holds outside of academia as well (NAE, 2004, p. 9). It seems improbable that the general phenomenon is isolated to academic settings.

Ethical quandaries abound for engineering students and engineering professionals, and there is no substantive reason to believe these issues will reverse trend and subside with the passage of time. To the contrary, "the engineer of 2020 will have to understand how to adapt solutions, in an ethical way, to the constraints of developing countries" (NAE, 2004, p. 21) and beyond. Modern examples teeming with ethical issues include: human gene editing with CRISPR (Bosley et al., 2015); the Volkswagen emissions scandal (Barrett et al., 2015); anthropogenic climate change (Allenby, 2004); deceptive practices in biotech companies like Theranos (Carreyrou, 2018), and privacy issues resulting from the continued development of black-box algorithms in artificial intelligence and Big Data (Mittelstadt, Allo, Taddeo, Wachter, & Floridi, 2016). As the trite saying goes, "with great power comes great responsibility", an idea some individuals have been espousing with regards to engineers since at least the 1970s (Unger, 1973). Davis (1991) takes this imperative further and points out that ethical behavior, and adherence to a code of ethics, in particular, is essential to engineering's status as a profession – not considering ethics forfeits engineers' status as members of a profession.

Ethical issues always abound in engineering, whether or not they are recognized as such. Indeed, one might further suggest that refusing to acknowledge the ethics inherent in engineering is symptomatic of the depoliticization in engineering that ignores the social and political issues embedded in engineering practice (Cech, 2013). It is less a question of whether or not we are teaching ethics and more a question of how well (or poorly) we are teaching ethics. Deciding not to teach *is still a choice* that does not make the ethical issues disappear.

On a language note, in this dissertation I will discuss engineering ethics as a "thing" because it is the topic of study – e.g., faculty members' mental models of *it*, how *it* is taught, factors that may affect when, where, and if *it* is taught. That kind of word choice is consistent with the extant literature and conversations about engineering ethics. Despite the prevalence of this perspective, there is considerable room for a more sustained conversation about the pitfalls of treating engineering ethics as a thing. For example, that framing could inadvertently transform ethics into an element that is separable from other parts of engineering education and practice. A more appropriate framing might be to frame ethics as a way of thinking. That is a conversation for a different venue. With this caveat in mind, I will adhere to the common parlance that discusses engineering ethics as object for this dissertation.

Engineering Ethics Education

How, then, might society hope to have engineers equipped with greater ethical sensitivity, knowledge, judgment, and willpower to meet the demands of modern engineering practice? One place, as noted elsewhere, could be the undergraduate engineering education system (Duderstadt, 2010; Gunsalus & Loui, 2013; NAE, 2004; Sheppard, Macatangay, Colby, & Sullivan, 2009). This general idea – that undergraduate education is a prime locus for helping students to continue developing their ethical judgment, sensitivity, knowledge, and willpower (King & Kitchener, 2004; Kohlberg, 1973; Kohlberg, Levine, & Hewer, 1983) – is even acknowledged in more formal mechanisms. In particular, the Accreditation Board for Engineering and Technology (ABET) recognizes this basic idea about the importance of engineering ethics instruction via student outcome 3.f, which stated that graduates of accredited engineering programs must have "an understanding of professional and ethical responsibility" (ABET, 2016). The updated accreditation standards reflect a similar idea in outcome 3.4: "an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts" (ABET, 2019]. This outcome comports with the expectations and requirements of the National Society of Professional Engineers (NSPE) and professional engineer licensure which heavily emphasize the importance of codes of ethics in order to distinguish engineering as a profession (Whitbeck, 2011, p. 8).

Unfortunately, even though undergraduate engineering ethics education is presumed to be important for future engineers, there exist deficiencies in the quantity and quality of engineering ethics education (Colby & Sullivan, 2008; Stephan, 1999). There is a range of ways faculty members teach engineering ethics, varying from the lower bound of "no deliberate ethics in the course" to the upper bound of "full integration, broad coverage". These faculty members may justify opposition to increasing quantity or improving quality of ethics instruction based on grounds ranging from their own lack of familiarity with the material to a stalwart belief in the irrelevance or superfluity of engineering ethics to the engineering curriculum (Hollander et al., 2009; NAE, 2016b). Those decisions are ethical choices themselves, and sweeping ethics under the rug only covers them up temporarily. As one participant in chapter three said, "these are things that you should think about all of the time." Engineering ethics is present in everything that an engineer does, regardless of whether they recognize it.

Nonetheless, obstinate opposition does not diminish the basic premise in numerous national reports and countless other writings: while technical proficiency may be a sine qua non of engineering graduates, ethical reasoning is also paramount (NAE, 2004, p. 52). Clearly, some faculty members believe in this importance while others do not. That difference in opinion can manifest in differentiated engineering ethics instruction. Survey data suggest this to be the case: engineering faculty members have varying views on the importance of ethics instruction, and, consequently, engineering ethics can appear in various places in engineering curricula depending on factors like disciplinary affiliation, course type, and personal characteristics such as work experience (Katz & Knight, 2017). This is relevant because these same individuals with diverse views on the importance of engineering ethics instruction are also capable of affecting the state of engineering ethics education in undergraduate engineering education. In turn, these qualitative and quantitative differences in engineering ethics education matter because deficiencies in engineering ethics education could affect ethical decision-making of professional engineers.

The Problem

So, why is there this gap in stated importance from national reports, professional engineering organizations, and accreditation standards on the one hand and actual practices in engineering programs on the other hand? Faculty members play a critical role. The general structure of engineering education play another important role. Of course, many developments in these education systems are path dependent, so history offers additional insights and context. In other words, individual agency, structural constraints, and historical traditions all contribute to the current state of engineering ethics education. Therefore, in order to more fully capture the interactions of agency and structure within engineering education and their effects on engineering ethics education, I designed this dissertation to consist of three parts. I have combined a study of faculty member mental models with data on the development of engineering ethics education and an exploratory theoretical study of the political economy of engineering education. These three approaches revolve around the central topic of engineering ethics education, and they inform each other. I illustrate this relationship in Figure 1.

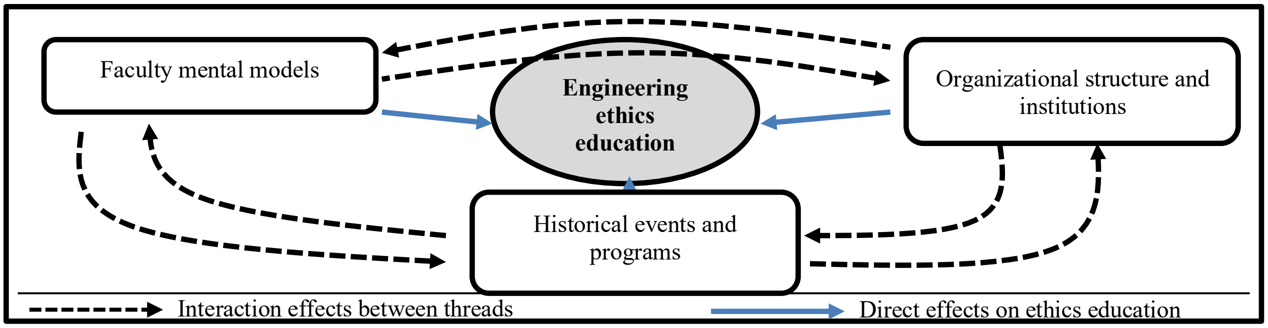

Figure 1. Three projects for understanding the state of engineering ethics education.

The projects in this dissertation cover the methodological range from an individualist perspective, looking at individual faculty members' mental models of engineering ethics education, to a more collective perspective. The collectivist approach focuses more on structural elements and aggregate behavior patterns within engineering education. For this dissertation I posit that the three projects together offer a more coherent picture for analyzing the state of U.S. engineering ethics education in part because they complement each other's limitations. The three threads in the dissertation are: a mental models approach focusing on individual faculty members; an historical approach for documenting and analyzing change in engineering ethics education as catalyzed, instigated, and enacted by trailblazing individuals embedded within and working to shape organizational and institutional structures; and a political economy approach to conceptualizing engineering education and engineering ethics education, incorporating ideas from academic fields such as sociology, economics, and political science. The complementarity of these approaches arises through their ability to consider different levels of analysis in unison – different levels which each play a role in affecting the state of engineering ethics education. This multifaceted approach is novel for engineering education research and offers a potential blueprint for future researchers. Having these three methods together bolsters triangulation to answer the research questions more completely by using the strengths in each approach in order to complement the limitations in the other approaches. By doing so, it is possible to account for the interplay of structure and agency all within the same project.

Conceptual Framework

Lattuca and Stark's (2009) academic plan model in Figure 2 provides the general conceptual framework I am using for investigating the state of engineering ethics education. The model depicts the academic plan – what is actually taught in a course – as an entity influenced by myriad factors. Those factors are both internal and external to the department (and university) in which the course is taught. I chose this framework because it captures the interplay between individual faculty members, departments, colleges, universities, accreditation bodies, professional societies, industry, governments, society writ large, and culture that can affect something like engineering ethics education.

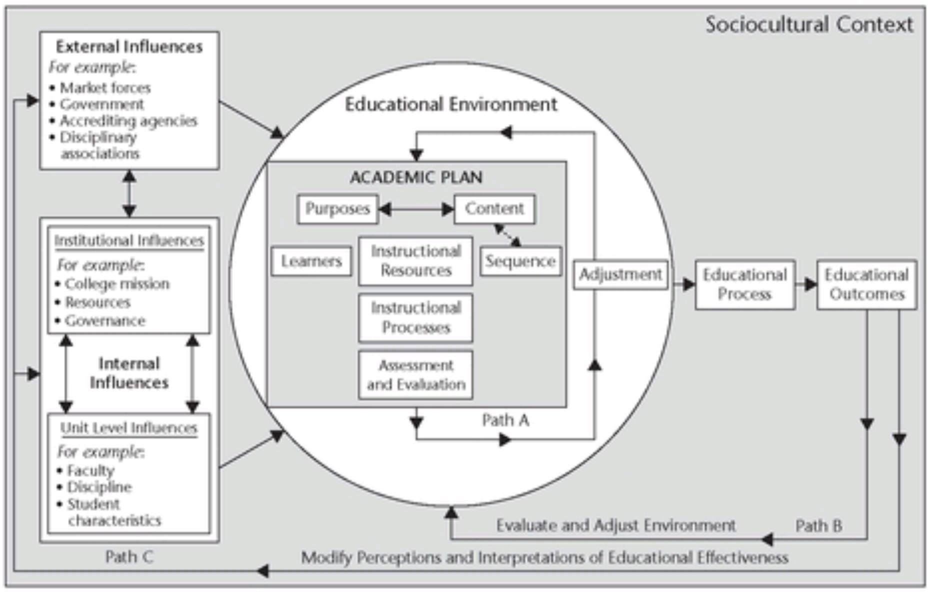

Figure 2. Lattuca and Stark's (2009) academic plan model.

In order to understand how these pieces might interact and impact engineering ethics education, I first start with the notion of structure – e.g., the structure of higher education engineering, the structure of engineering education, the structure of universities, etc. These structures provide the schemas and resources in which institutions, organizations, and individuals operate. Within that structure is a political economy of engineering education that establishes the logics that help inform and guide interactions among entities within the system. It is part of, but not synonymous with, the idea of structure.

Alongside the political economy of engineering education is the general political economy of higher education and the notion of academic capitalism, which speaks to the particular incentives and behavior of faculty members in a system of universities operating like businesses. Notably, universities themselves are examples of organizations rather than institutions because they are legal entities capable of performing acts. Institutions, on the other hand, are the informal and formal "rules of the game", which could include something like formalized accreditation standards or the informal norm of a professor preferring project-based learning in lieu of lecture-based classes. Institutions are important to my project because they contribute to the overall structure of engineering education, informing mental models that faculty members have, which in turn informs their behavior in the system (Denzau & North, 1994). The upshot of these larger notions is the creation of an environment in which individuals can act; yet, the structure is not static. There is an interplay between structure and agency. Thus, when considering these concepts, it is important to recognize the individual actor's role in helping to perpetuate (or change) these reified entities.

Focusing more on the individual faculty members, one can begin with the notion of ideologies, which are the systems of belief that help interpret, explain, and justify the environmental conditions and discrete events. Faculty members harbor these ideologies that consequently help inform their classroom and curricular choices. More specifically, faculty members possess mental models – ways of describing, explaining, and predicting the form, function, state, and purpose of a system (Rouse & Morris, 1986) – that inform their interpretations of the environment and shape their decisions. Acknowledging the potential relevance of these mental models in affecting the state of ethics education, I studied the mental models of faculty members of engineering ethics education. In doing so, I am assuming that these faculty members are exercising some form of agency in their decision-making, otherwise the study of faculty member mental models would be gratuitous; hence, agency, faculty agency, and faculty decision-making are all relevant concepts in my work.

Recognizing that faculty members are embedded agents within a larger structure consisting of organizations and institutions, it is also important to acknowledge the bounded rationality of these agents (Kahneman, 2003; March, 1978; Simon, 1955, 1991). These individuals are not necessarily perfectly calculating automata. Similarly, the structure itself is not infallible, nor is it immutable; thus, the concepts of organizational change in engineering education and institutional entrepreneurship are relevant as ways to understand the dynamic state of engineering education. Indeed, analyzing historical accounts of institutional entrepreneurs who envisioned and enacted change within the structure and institutions of engineering ethics education provides detailed insight into interactions of structures and agents.

All of these concepts hang together to represent a model in which the structure of engineering education, as characterized by its institutions and culture, affects faculty member ideologies and mental models. The political economy of engineering education – the relationships and logics established under resource dependencies and allocations decisions (Weingast & Wittman, 2006) – further adds to this picture. It fits into the "sociocultural context" and "external influences" sections of the academic plan model in Figure 2 but extends the model since they never explicitly use that framing of political economy in their work. From that starting point, relationships form within departments and classrooms, consequently influencing engineering education.

Against this backdrop of the political economy of engineering education, faculty members then use their mental models to guide their decisions as they exercise agency over their classroom and the engineering curriculum. If the system were static over time then that might be the end of the conversation; however, these elements and processes are dynamic. This dynamism within engineering ethics education, represented by organizational and institutional changes, arises in part from institutional entrepreneurs who are embedded within the structures themselves. Consequently, in order to understand the state of U.S. engineering ethics education, I created three threads for my dissertation. The following project overview delineates my particular research questions and methods that I used to answer those questions about the state of U.S. engineering ethics education by accounting for this interplay between structure and agency.

Projects Overview

As mentioned previously, this dissertation contains three complementary projects: (1) analyzing the stories of pioneers who helped change the state of the system over time; (2) characterizing the mental models of engineering faculty members of engineering ethics education; and (3) delineating a theoretical framework for characterizing the political economy of engineering education with a particular focus on engineering ethics education. Each project is a separate chapter (chapters two, three, and four, respectively). The following sections outline the constituent elements for each study, i.e., a brief introduction of the motivation, background, data collection, and analysis. Table 1 provides a synopsis of this project overview.

Table 1. Overview of dissertation projects.

Proposed Dissertation Project Components			
Project Thread	Historical Perspectives of Changes in Engineering Ethics Ed	Faculty Member Mental Models of Engineering Ethics Ed	Political Economy of Engineering Education
Research Question(s)	(a) How has U.S. engineering ethics education changed since 1970? (b) What are the common themes in the stories of engineering ethics education trailblazers?	What are the mental models that engineering faculty members possess of engineering ethics education?	How might the political economy of engineering education affect decision-making processes concerning engineering ethics education?
Methodology	First-person narratives	Mental models	Literature review; Concept mapping
Data Collection	11 written accounts + 1 interview	25 mental models interviews	Narrative literature review (10 concepts)
Data Analysis	Thematic analysis	Mental models coding	Thematic analysis
Level of Analysis	Primary: Individual Secondary: Structural	Primary: Individual Secondary: Structural	Primary: Structural Secondary: Individual
Unit of Analysis	Narrative accounts	Mental models	Political economy & higher education models

Chapter 2: Historical Developments in the State of Engineering Ethics Education

The education process designed to encourage students to recognize the ethical dimensions of their work typically starts during a student's undergraduate studies; however, the form and function of engineering ethics education, including its mere existence, are neither uniform across the current U.S. engineering education landscape nor have they been static over time. Despite the importance of engineering ethics for professional practice, engineering ethics has not always been taught in undergraduate engineering programs (Mitcham, 2009; NSPE, 1963). For example, content has gone from a limited set of negative mandates – do not accept kickbacks or bribes and do not malign other engineers (Baum, 1980) – to a more expansive view introducing students to professional codes of ethics, discussing relevant ethical frameworks to apply to ethical dilemmas that arise in the course of engineering practice, and questioning the ultimate purpose(s) of engineering projects (Colby and Sullivan, 2008; Herkert, 2005). Through the concerted efforts of numerous people across multiple decades, engineering ethics even became institutionalized as

ABET criterion 3.f (now 3.4) (ABET, 2016). This is not to say that all is currently at an optimal homeostasis in the state of engineering ethics education. For example, there exist different approaches on how best to teach it (Newberry, 2004), how to research it (Hess & Fore, 2017), and even the vision of what it should contain (Catalano, 2006; Gurnham, 1962; Harris, Davis, Pritchard, & Rabins, 1996; Herkert, 2001, 2005; Pantazidou & Nair, 1999; Riley, 2008; Whitbeck, 1995).

Alongside these conversations, there have been substantive changes over time. To understand the present, characterizing the past may help. However, the drivers of those changes have hitherto infrequently documented their experiences in heralding that change. Mitcham (2009) documented the general stages in the progression. Hollander and Steneck (1990) discussed developments in the Ethics and Values in Science and Technology program at NSF, but even this was only tangentially related to engineering ethics education. There simply do not exist many publications that provide first person accounts of changes in engineering ethics education or analysis of said accounts. At a minimum, answering the question of historical development from their perspectives affords an opportunity to characterize systemic changes and glean lessons for future change agents and institutional entrepreneurs in engineering ethics education, engineering education, and STEM education more broadly. Furthermore, if not documented via appropriate methods like oral histories in the proximal future, collections of personal and institutional knowledge may be lost for perpetuity given the age of some of the pioneers.

Against this backdrop, project one of this dissertation is a project about historical changes in the norms and practices of U.S. engineering ethics education from the perspectives of the individuals who helped envision and implement that transformation. This part of the dissertation permits analysis at both the individualist and structural ends of the spectrum, thus aiming to avoid the simplistic, linear "great actor" version of history. The data come from written narratives from the trailblazers in engineering ethics education and an additional interview. The narratives themselves, and their analysis, will help address the gap in understanding how engineering ethics education has reached its current state. At its core, this project focuses on documenting (a) experiences for posterity, (b) change processes in ethics education, (c) the historical interplay between structure and agency in engineering ethics education, and (d) common themes in the trailblazers' narratives.

Research question 1

(a) How has U.S. engineering ethics education changed since 1970? (b) What are common themes in the trailblazers' stories of change in engineering ethics education? (c) What do those themes reveal about change processes and mechanisms in engineering education?

Strategy to answer RQ 1

Data for this project come from chapters that I have collected for an edited volume. I submitted a prospectus for this volume to Purdue University Press, and they expressed interest in printing it. The list of contributing participants includes: Michael Davis, Charles Harris, Joe Herkert, Rachelle Hollander, Deborah Johnson, Heinz Leugenbiehl, Michael Loui, Rosa Lynn Pinkus, Mike Martin, Carl Mitcham, Michael Pritchard, and Larry Shuman. Individuals were invited to contribute based on their sustained involvement in engineering ethics and engineering ethics education over multiple decades dating back to the 1970s and 1980s.

For this project, I sent invitation emails to each trailblazer in order to ascertain their interest in the project, availability, and which mode of data collection they would prefer – authoring a written account or participating in an interview that I would later transcribe. Three invitees never responded. Of those who did respond, all but one elected to write their own chapter. With these written accounts, I engaged in thematic analysis of the narratives across the three categories related to interpersonal relationships, structural and organizational interactions, and incentivizing change.

Chapter 3: Faculty Mental Models of Engineering Ethics Education & Engineering Ethics

For project two of my dissertation, I address the gap in understanding faculty members' decision-making about engineering ethics education by characterizing their mental models – internal representations of systems and process (Johnson-Laird, 1983; Khemlani, Barbey, & Johnson-Laird, 2014; Morgan, Fischhoff, Bostrom, & Atman, 2002; Rouse & Morris, 1986) – of engineering ethics education. The underlying assumption is the premise that different mental models inform faculty course planning choices, which manifest as differential pedagogies and curricula of engineering ethics in engineering courses. Given the variety in pedagogical approaches (Bairaktarova & Woodcock, 2015; Davis, 2006; Graber & Pionke, 2006; Haws, 2001; Herkert, 2000; Loui, 2005), I anticipated that there would be a panoply of potential mental models that faculty members utilize. In the same vein, I anticipated that it would be important to look at engineering faculty members in multiple disciplines since there is evidence to suggest that academic discipline can strongly influence professional and curricular decisions (Lattuca, Terenzini, Harper, & Yin, 2009; Smart, Feldman, & Ethington, 2000). Other factors that affect engineering faculty member curricular decisions are time, personal values such as family responsibility, and preparing students for the needs of industry as factors that affect their curricular decisions (Huang, Yellin, & Turns, 2007). In prior research, faculty member rank and gender have also been correlated with differences in how they allocate their time among teaching, research, and service (Link, Swann, & Bozeman, 2008). More generally, institutional constraints, personal beliefs, affective orientations and experiences may further affect faculty members' judgments (Shavelson & Stern, 1981). To clarify this last point, Kagan (1992) defines teacher beliefs as "tacit, often unconsciously held assumptions about students, classrooms, and the academic material to be taught." The point here is to emphasize the potential interactions between faculty member mental models and curricular outcomes, e.g., engineering ethics education.

Research question 2

What are the mental models that engineering faculty members possess of engineering ethics education?

Strategy to answer RQ 2

To answer research question two, I have interviewed 25 faculty members from civil, mechanical, and electrical engineering departments across the United States. These three disciplines are chosen in order to provide a broad range of attitudes about engineering ethics education since there is evidence to suggest that differences exist in faculty member perspectives of engineering ethics across these disciplines (Katz and Knight, 2017). I followed a method based on recommendations from Morgan et al. (2002). I developed and used a semi-structured interview protocol. Having 25 interviews allowed for a high degree of conceptual saturation after which each additional interview yielded a diminishing amount of information (i.e. diminishing marginal information), as expected according to Morgan et al. (2002, p. 76).

Data analysis

I analyzed the mental models interviews following the protocol that Morgan et al. (2002) outline. Specifically, I qualitatively analyzed the interview transcripts with a combination of *a* *priori* codes and inductive codes using the software package NVivo 12. Doing this allowed me to identify the entities and relationships between those entities in faculty members' mental models in ten different areas. Those 10 areas are: (1) definitions of ethics, (2) contents of ethics education, (3) why teach ethics, (4) where students learn ethics, (5) when students learn ethics, (6) when ethics is taught, (7) who makes decisions about ethics, (8) who teaches ethics, (9) how faculty members can teach ethics, and (10) how students learn engineering ethics.

In addition to providing insight into faculty members' mental models of engineering ethics education, these interviews also revealed evidence for the third project on the effects of the political economy of engineering education.

Chapter 4: Political Economy and Engineering Ethics Education

The other two projects focused primarily on individuals and their agency in order to understand the state of engineering ethics education. The limitation in those approaches is their relative neglect of structural factors that can affect engineering ethics education. The third project addresses such a limitation by looking at the political economy of engineering education. This involves characterizing the power relationships and decisions surrounding resource allocation in engineering education that arise as the result of political and economic circumstances shaping engineering education.

Of course, many of those same circumstances have been affecting higher education more generally. Over the past several decades, higher education has shown signs of being treated like a market good (Becker & Toutkoushian, 2013; Dill, 1997; Newman & Jahdi, 2009). Universities have increasingly operated like businesses (Connell, 2013; Washburn, 2005), students have occupied the role of consumer (Bunce, Baird, & Jones, 2017; Molesworth, Nixon, & Scullion, 2009; Tomlinson, 2017), and governments have appropriated funds accordingly (Dougherty et al., 2014; Kallison & Cohen, 2010; Li, 2017). With the spread of academic capitalism comes an entire set of concepts and logics that affect engineering education, especially given its placement within the higher education landscape. For example, university emphasis on generating grant revenue could shift engineering faculty member time and interests away from efforts to incorporate engineering ethics into their courses. Alternatively, philanthropic donations could provide the resources to run a summer faculty training workshop to help faculty members include engineering ethics in their courses. In either scenario, and countless others like these, there are factors external to the faculty members that are affecting engineering ethics education.

In an attempt to acknowledge and address such contingencies in light of the aforementioned institutional changes, for project three I have outlined relationships and dependencies driving behavior in engineering education. To do this, I have asked how the political economy of engineering education can affect resource (e.g., time, space, money, attention) allocation decisions surrounding engineering ethics education. This entailed developing a research agenda that highlights relevant concepts, identifies research questions, and envisions the application of models from political economy to engineering education and engineering ethics education.

The third thread builds upon the foundational idea of individual faculty members as not only autonomous actors but also as embedded actors within political and economic structures, e.g., organizations, institutions, cultures. While faculty members may have their own individual mental models, their actions are not solely informed by those mental models of engineering ethics/engineering ethics education. There are contextual factors that can also play a role. Thus, this thread focuses on the consequential effects of the political economy of engineering education on engineering ethics education. It is the most theoretical of the three projects.

Research question 3

How might the political economy of engineering education affect decision-making processes concerning engineering education, and engineering ethics education in particular?

Strategy to answer RQ 3

I have taken a theoretical tack to answer research question three. In particular, I have drawn upon ideas from disparate fields within political economy to highlight relevant phenomena in the field of engineering education through a narrative literature review (Grant & Booth, 2009; Paré, Trudel, Jaana, & Kitsiou, 2015). I used quotes from the mental models interviews to illustrate actual places where these phenomena arise. Those examples lend an element of concreteness rather than pure abstractness. I then articulated pertinent research questions, and considered how those concepts could help researchers, administrators, and faculty members to understand aspects of engineering education, i.e., the state of engineering ethics education. In total, I identified ten theoretical phenomena (six in the chapter and four in an appendix) that help answer this research question and also point to future areas of research in engineering education.

Project Limitations

The lines of inquiry in this dissertation make several assumptions with potential limitations. First, there is an assumption that faculty members possess a discernible, finite, number of mental models of engineering ethics education. This would require characterizing the mental models of the interviewed faculty members and sorting those collected models into grouped representations based on similarities. The pooling process introduces an element of indeterminacy to the method since there is no *a priori* way to determine how many models a faculty member could actually have at one time. In theory, there are myriad permutations of the identified models that a faculty member could have. In reality, however, there were minimal indications in the data of this ballooning. Additional limitations with the mental models study revolve around the mutability of these models, their stability over time, their parsimonious inclusion of a small number of entities, and the degree to which mental models inform faculty member pedagogical and curricular decisions. These are general limitations to mental models that have been noted in literature (Doyle & Ford, 1999; Norman, 1983). In chapter three I expound upon steps that I took to reduce these limitations.

There are other limitations associated with the historical and theoretical political economy lines of inquiry. For the historical thread addressing research question one, these include: hindsight bias – the retrospective impression that one "always knew something", even if that is false (Roese & Vohs, 2012) – and selection bias in personal memory – selectively remembering specific events (Chung, 2010) – and selection bias in which narratives to incorporate (Lustick, 1996). There were certainly more than 12 trailblazers who helped develop engineering ethics education, and their stories may have revealed different important themes to answer research question two. However, I mitigated this limitation by collecting stories from people in different institutional settings, various disciplines, and different approaches to change, which helped capture the variety of stories and perspectives to change in engineering ethics education. Other limitations include source transparency and alternative interpretations (Bryant, 2000; Bucheli, Kipping, & Wadhwani, 2015). I address these issues in chapter two. For chapter four, on the political economy of engineering education, limitations might include: the abstract nature of the inquiry and eventual applicability of the identified phenomena. There is also a possibility of general incompleteness from not having interviews with university administrators, government officials, or industry representatives whose decisions also affect engineering education, but that issue was beyond the scope of this dissertation.

Concluding Remarks

My holistic approach to studying the state of engineering ethics education provides valuable insights unattainable with a more atomistic study of individual faculty members or structural investigation alone. Moreover, each part complements some of the other parts' weaknesses. Individualist approaches lose focus of the structural and institutional elements. Collectivist approaches can lose sight of the individual faculty member's role and power in the classroom. The three parts together enable different ways to account for structure and agency – an individual's ability to make autonomous choices that affect their environment. Figure 3 shows how much each project emphasizes structure and agency. In particular, chapter two (the history project) balances structure and agency while chapter three (the mental models project) is higher on agency than structure and chapter four (the political economy project) is the converse.

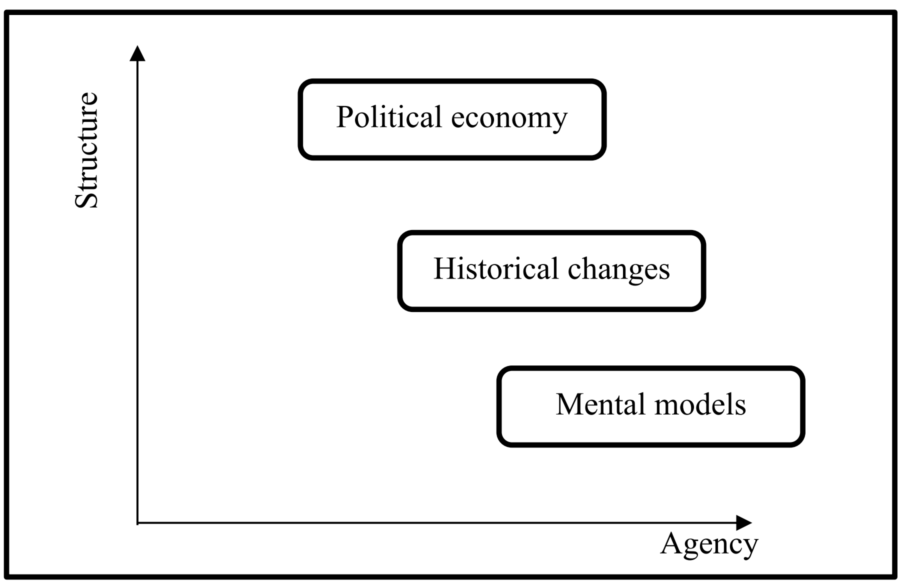

Figure 3. The balance between emphasizing structure and agency for the three projects

In some ways, this dissertation is about engineering education as a system. That perspective involves looking at faculty as a constituent component of that system and then further looking at engineering ethics as a test case of the inner workings of the system to create a general model of engineering (ethics) education. This point is where the political economy lens becomes relevant, because that, too, analyzes the observed phenomena as part of a system. In other words, this dissertation uses three methods for modeling the engineering education system. Of course, it is important to remember the limitations of modeling, whether that be modeling engineering education as a collection of institutions and organizations or characterizing the mental models of faculty members. As Box and Draper (1987, p. 424) state, “essentially, all models are wrong, but some are useful”. In this spirit, the following chapters expound upon some useful ways to understand the state of engineering ethics education.

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CHAPTER 2: HISTORIES OF ENGINEERING ETHICS EDUCATION

Preface

Prior to the 1970s, engineering ethics education comprised a narrow range of concepts and occupied a circumscribed position within the undergraduate engineering curriculum. Ethics was typically synonymous with dictates of professional conduct and relegated to a course on professionalism. Jump ahead 50 years in time and the engineering ethics education landscape looks different—it is more encompassing. In contrast with the past, engineering ethics now consists of more topics, occupies a larger part of the average engineering curriculum, and supports an entire field of study. Although many would observe that there exists ample room for improvement in today's undergraduate engineering ethics education, there has clearly been notable movement over the past decades. These changes raise the question: how did this transformation arise? To be sure, it was a combination of factors—personal interests, interpersonal collaborations, institutional incentives, and luck, to name a few. The trailblazers in the field all have their own answers to the mechanics of change. This chapter reviews some of the common elements and themes – organized into three categories: interpersonal, institutions and organizations, resource dependence – among the trailblazers' stories. The review not only helps to answer the question of how these changes arose but also highlights broader lessons for anyone interested in bringing further changes to engineering education, both in ethics education and beyond. Similarly, these lessons should appeal to people working on organizational and institutional evolution.

Introduction: What are some of the changes?

Although ethics may be an important consideration in contemporary engineering practice (NAE, 2004, p. 5), there was a time not long ago when conversations about engineering ethics and engineering ethics education were limited in their scope and appeal (Unger, 1973). The topics often revolved around issues of professional practice, such as not accepting kickbacks, not maligning a fellow engineer, or not underbidding competition (Baum, 1980). Weil (1984) suggests that the 1970s were the time when engineers, social scientists, and humanists began joining efforts to form the field of engineering ethics. These efforts started in the aftermath of Watergate, the Vietnam War, and the rise of environmental and consumer protection movements. The engineering ethics community was building upon writings from the 1960s like Rachel Carson's *Silent Spring* (1962) and Ralph Nader's *Unsafe At Any Speed* (1965). This community's work in the past 45 years has expanded the conversations and understandings of how engineers should act in their professional capacities.

The authors in this volume describe personal, organizational, and institutional factors that have helped (and hindered) the development of engineering ethics and ethics education since the early 1970s. Although their stories are each unique, they also share common themes. For example, each author references an element of resource dependence — typically in the form of funding for projects — as a rate-limiting factor in developing the field. At times when resources were plentiful, developments in curricula, scholarship, and collaborations continued apace. In times of reduced resources, those types of developments began to stall. For a second example, exogenous shocks to the ethics education system in the form of large, public engineering accidents or scandals provided catalysts to the field's evolution. The Challenger explosion is one such disaster that provided a wake-up call to the community, especially those previously disinterested in engineering ethics, and fodder for those already working in this space. In this chapter, I will briefly review the state of engineering ethics and ethics education before 1970, discuss some changes to that state over the past 50 years, and explore themes in the stories of those who had firsthand experience introducing and promoting those changes. The themes cluster into three categories, interpersonal, institutional and organizational, and resource dependence. Those categories and their associated themes offer two different benefits: (1) ways to understand the current state of engineering ethics education and (2) focal points for anyone interested in future changes to target in their own work.

Engineering Ethics and Ethics Education Before 1970

Before analyzing the trailblazers' accounts of how engineering ethics education developed after 1970, it is helpful to characterize the state of engineering ethics education heading into that decade. Focusing on the pre-1970s era, one can take a further step back before asking about engineering ethics education and ask, what did engineering ethics even mean at that time? Answering this question rewinds the scene to the early 20th century. At that point in time, engineers were still engaged in external and internal struggles to define what it meant to be an engineer and engineers' roles in society (Layton, 1971; Meiksins, 1988). Was it about responsibility for social progress (Christie, 1922)? Something associated with establishing the prestige and autonomy of being a profession (MacIver, 1922)? Layton suggests the answer to both of those is “yes”.

Engineering ethics education was similarly inchoate and in flux. In a publication from the Hastings Center, Baum (1980) reviewed ethics instruction in engineering in the mid 20th century. The image he painted in that short book was a constrained one. The common topics covered in engineering curricula were primarily related to professional conduct – do not accept kickbacks, do not malign a fellow engineer, be honest. Nowadays, the list of topics and learning outcomes has expanded to include concepts beyond professional conduct and into the macroethical issues inherent in engineering practice (Hollander, Arenberg, & National Academy of Engineering, 2009). The following section explores some of the changes in meanings and practices in engineering ethics and education over the past 45 years. Appendix 1 has a more extended list of events in engineering ethics and engineering ethics education over the past 100 years.

Mapping Some Changes

Comparing the meanings of engineering ethics before 1970 with those of 2019, there are inescapable differences. The same is true when contrasting the practices of engineering ethics education before 1970 with those of today. In other words, changes occurred. The following section explores some of those changes.

Evolving definitions

The meanings and practices around engineering ethics and engineering ethics education have evolved over the past 50 years. Mitcham (2009) outlines how some of these changes arose in phases starting with implicit ethics, transitioning to loyalty between the engineers and business, and culminating in a more expansive mandate that engineers hold paramount the health, safety, and welfare of the public. Under this view, engineers have incorporated more explicit social responsibility in their understandings of ethical behavior over time. Consider professional codes of ethics, for example. The National Society of Professional Engineers (NSPE), which did not even have a code of ethics before 1947 (Baum, 1980, p. 9), adopted the paramountcy clause – that engineers shall hold paramount the health, safety, and welfare of the public – in 1974. Other professional societies, e.g., the American Society of Civil Engineers (ASCE), adopted their first code of ethics in 1914 (Pfatteicher, 2003). They have continued to amend their codes since then by accounting for increased environmental concerns (as with ASCE (Vesilind, 1995)), the global reach of their codes given international membership (as with IEEE (Pugh, 2009)), and the need to pursue diversity, equity, and inclusion both within the profession and in serving communities (ASCE, 2019). Of course, there have been setbacks along the way. Unger describes as “an assault” on the ethics support work by the IEEE Executive Committee that the organization’s Ethics Committee had done in the early 1990s (Unger, 1999). Overall, the changes have been positive, but neither constant nor uniform in their direction.

Within the academy, there have also been changes in definitions and practices around engineering ethics and education. Starting over 100 years ago, in 1918 the Mann report briefly mentioned ethics once as part of a litany of factors that distinguish a problem as being more realistic (Mann, 1918). By 1955, ethics was incorporated into the technical and social objectives that the Grinter report identified as important for engineering education: “the broad social goal of engineering education, includes the development of leadership, the inculcation of a deep sense of professional ethics, and the general education of the individuals” (Grinter, 1955). The engineering ethics requirement remained nebulous over the next thirty years. Harris, Pritchard, and Rabins (2005) observe that thirty years later, in 1985, ABET did expect programs to teach “an understanding of the ethical characteristics of the engineering profession”. This remained the status quo until the turn of the century.

One of the more salient changes came from the Accreditation Board for Engineering and Technology (ABET) changing its accreditation standards in 1996 (Lattuca, Terenzini, & Volkwein, 2006). The new standards, called EC2000, included a student learning outcome (3.f) that students should have “an understanding of professional and ethical responsibility” (ABET, 2004). As Gunsalus and Loui (2013) point out, this was the first time that ABET began requiring programs to assess students on ethics-related outcomes. This accreditation change created a more explicit expectation that programs incorporate engineering ethics in their curricula. Given the timing, it also means that the trailblazers were operating in both pre- and post-EC2000 environments. Faculty members today know that engineering ethics is more difficult to ignore now than it was before EC2000. As a result, we may not expect to see the same patterns of change in the future as the trailblazers experienced.

Around the same time that EC2000 was changing the conversation around ethics education in engineering departments, Herkert (2001, 2005) published a couple of popular articles arguing for a definitional refinement: a distinction between microethics and macroethics in engineering ethics. By calling attention to the different levels at which ethical decision-making can arise in engineering practice, Herkert helped contribute to these evolving conversations and understandings about engineering ethics. Mitcham (2009) traces how that conversation has evolved in phases from (i) implicit ethics to (ii) ethics as loyalty to (iii) ethics as efficiency and finally to (iv) ethics as public health, safety, and welfare. More generally, in their chapters, the trailblazers also noted evolving meanings in their own thoughts on ethics. Harris (1995, 2013), for example, has previously described his move from a focus on preventive ethics – dictates to avoid certain activities like bribery or cheating – toward a focus on aspirational ethics.

To be sure, there is still room for improvement. In her chapter, for example, Hollander highlights the need to incorporate more marginalized voices in the classroom. The same could be said for incorporating more voices into the creation and evolution of codes of ethics to incorporate values like social justice (Riley & Lambrinidou, 2015; Riley, Slaton, & Herkert, 2015). Nonetheless, there have been changes, both precipitous and gradual. Those changes themselves have sometimes been realized amidst the backdrop of acute and chronic events that mark additional changes in engineering ethics and engineering ethics education over that past decades. The next section discusses some of those events.

Events that set scenes

A collection of publicly visible events and more private events with selective participants has set the scenes for changes in engineering ethics and engineering ethics education. The most conspicuous class of public events has been engineering disasters. These accidents highlighted the relationships between engineering and society, and they commonly implicated ethical decision-making as part of their cause. The list of events in the 1970s and 1980s (and examples of ensuing publications they inspired) includes:

- Ford Pinto case in 1972-73 (De George, 1981),
- Bay Area Rapid Transit case in 1972-73 (Friedlander, 1974; Unger, 1973b),
- DC-10 Turkish Airlines crash in 1974 (Fielder & Birsch, 1992),
- Love Canal and Valley of the Drums gaining publicity in the late 1970s (Bolsen, 1981; Fitchen, Heath, & Fessenden-Raden, 1987),
- Three Mile Island nuclear accident in 1979 (Herkert, 1994),

- Hyatt Regency Walkway collapse in 1981 (Pfatteicher, 2000),
- Bhopal pesticide plant leak in 1984 (Dhara & Dhara, 1995; Jasanoff, 1988),
- Chernobyl nuclear accident in 1986 (Wilson, 2013),
- Challenger Shuttle explosion in 1986 (Boisjoly, Curtis, & Mellican, 1989; Pinkus, Shuman, Hummon, & Wolfe, 1997), and
- Exxon Valdez oil spill in 1989 (Shrivastava, 1994).

These events fueled action, advocacy, scholarship, and critical examination of the relationship between engineering and society. These events and others – like Watergate and the revelation of the Tuskegee airmen case (Brandt, 1978) that put ethics in the public sphere – provided fodder for those looking to draw attention to the importance of ethical decision-making in engineering practice, as some of the references indicate. With these highly visible events, people in the engineering ethics education community had tangible examples to help make the case for their work's necessity. In the same vein, these engineering disasters provided material for writing case studies, publications, and pedagogical materials for engineering courses. By drawing on these disasters as inspiration for change, the engineering ethics community advanced the conversation about engineers and their normative behavior – what engineers *should* do.

Many conversations about ethical behaviors in engineering transpired at less public events like conferences and workshops, helping to fuel scholarship and meanings in engineering ethics education. The trailblazers mention some of these conferences and workshops in their chapters. Various professional organizations such as the National Academy of Engineering (NAE), National Science Foundation (NSF), American Society for Engineering Education (ASEE), Association for Practical and Professional Ethics (APPE), and Institute of Electrical and Electronics Engineers (IEEE) helped sponsor these opportunities over the years. There have been annual conferences from APPE (started in 1992), Frontiers in Education (FIE) (started in 1971), or ASEE, which host papers, presentations, and discussions on engineering ethics without being dedicated specifically to the topic. Whereas the APPE annual conference is about many areas of professional ethics, the ASEE and FIE annual conferences are broadly about engineering education and have portions on engineering ethics education.

There have also been one-time workshops and conferences like the American Association for the Advancement of Science (AAAS)-sponsored workshop on Interrelationships Between

Science and Technology, and Ethics and Values in 1975 (McGinn, 1976). In the early 1980s there was the NSF-sponsored National Conference on Ethics in Engineering (Weil, 1983). Later in the decade was the agenda-setting workshop for the Ethics and Values in Society Program at NSF in 1988 (Waks, 1993). These conferences and workshops, whether they were recurring events or one-time occasions, provided venues for people to come together and develop the field of engineering ethics. The larger takeaway message here is that a broad spectrum of public and private events have been part of the changing engineering ethics and engineering ethics education landscape during the past 50 years.

Growth in scholarship

Another change in the field of engineering ethics over the past 50 years has been the growth in the scholarly articles related to engineering ethics and engineering ethics education. Journals, especially new ones, were part of that story. New publication outlets included *Science and Engineering Ethics*, created in 1995, and *Business and Professional Ethics*, created in 1981, and the IEEE's *Technology and Society*, created in 1977. More outlets equated to more articles on the topic of engineering ethics. Likewise, more articles on the topic meant more opportunities to push the conversation forward.

To see the increase in ethics-related articles entering the scholarly conversation, let us focus on engineering ethics education. Moreover, let's return back to the topic of conferences and glimpse trends in conference publications for the American Society for Engineering Education (ASEE). The ASEE Papers for Engineering Education Repository (PEER) has abstracts and articles from ASEE conferences dating back to 1996 up until 2018. The articles in the database are freely available for public viewing. Searching for "ethics" in this database shows that there has generally been a year-over-year increase in the number of articles mentioning ethics (either directly or indirectly). This comes with the caveat that the database search options are coarse and may return articles that are only peripherally related to ethics. Nonetheless, these search results may be instructive for indicating general trends over time. Figure 4 shows the counts of ethics articles for each year as well as the total number of articles per year. In general, there has been an increase in the count of articles returned in the "ethics" search over the past 23 years. To be sure, there has been a growth in the total number of articles in the database for each year, but there has also been growth in the number of articles returned in the "ethics" search as a proportion of the total number of articles (Figure 5). One might expect growth in the total number of articles in the database given the growth in the field of engineering education. Growth in the number of ethics articles, on the other hand, may be less expected, and it provides evidence of the general growth in conversations about engineering ethics over that time period.

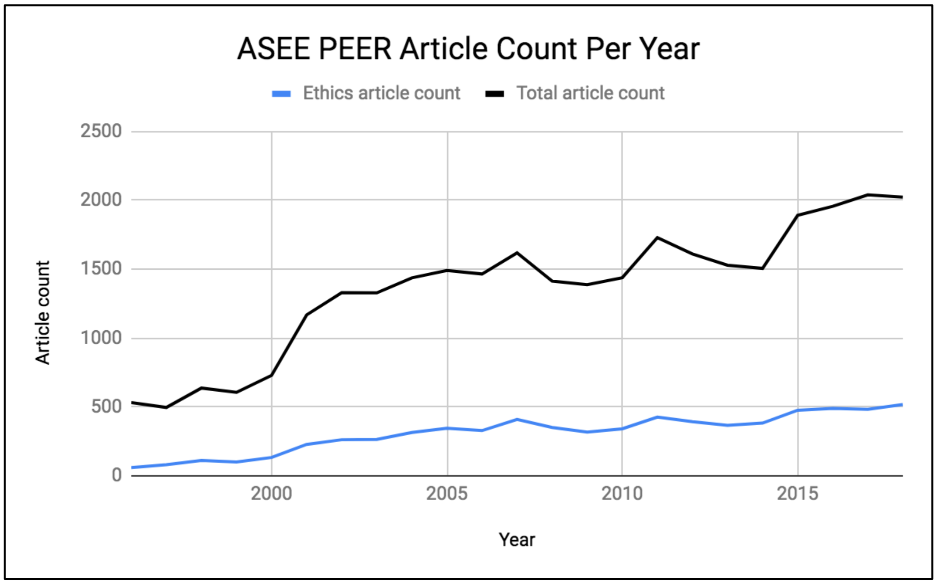

Figure 4. Growth in total articles from 1996 to 2018

Figure 5 adds to this point by illustrating how the proportion of ethics-related articles as a percentage of the total number of articles in the database for that year has changed. Again, there is a large jump around the early 2000s. That jump is possibly connected with the creation of the Ethics Division (in 2006) and Liberal Education Division (in 2011) as well as the change in Accreditation Board for Engineering and Technology (ABET) accreditation standards to EC2000. Those standards had a specific student outcome (3.f) that engineering students should have an understanding of professional and ethical responsibilities, as mentioned above. That move sent engineering program administrators scrambling to figure out how to teach and assess engineering ethics instruction (Pfatteicher, 2001; Shuman, Besterfield-Sacre, & McGourty, 2005). Consequently, one may expect to see a concomitant increase in ethics-related articles at an engineering education conference. The persistence for ethics-mentioning abstracts or articles to remain above 20% of the total number of entries, on the other hand, is an interesting data point suggesting this overall growth in engineering ethics-related scholarship over the past several decades.

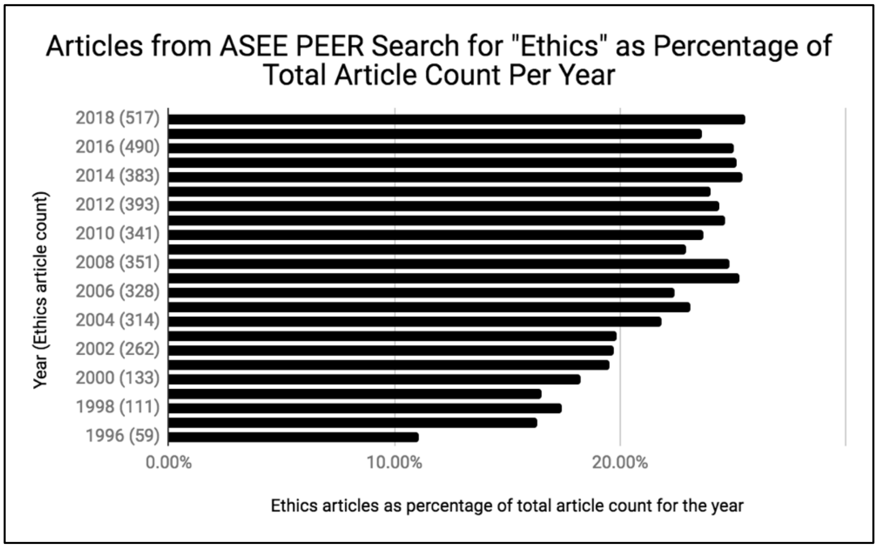

Figure 5. Percentage of total articles per year that mention ethics

The overall picture here is one in which changes in engineering ethics – definitional, communal, public, professional – have transpired over the past 50 years. Sometimes that change has been sudden. Other times there has been a more protracted process. The authors in this book describe some of their own experiences in making those changes come to fruition. Although they each have unique stories to tell, when identifying broader lessons for anyone interested in (a) engineering ethics, (b) education, (c) institutions, and/or (d) organizational change, it can be instructive to ask, what are some of the common themes among the different stories? Answering this question can do at least two things. First, it can contextualize the current state of engineering ethics education, helping to explain why engineering ethics education looks the way it currently does. Second, these themes identify strategies, opportunities, and obstacles for change agents to consider and address when thinking about future change in many areas, including but not limited to engineering ethics education. With these goals in mind, the following section outlines some of those commonalities among the trailblazers' stories.

Common Threads in the Stories: What are some of the common themes?

The trailblazers' stories have shared themes even though each person has their own story to tell. I identified these themes by an approach loosely informed by thematic analysis. Thematic analysis is a general qualitative research method for analyzing text based on recurring themes and patterns (Clarke & Braun, 2017; Guest, MacQueen, & Namey, 2012). Thematic analysis commonly proceeds using a procedure similar to Braun and Clarke's (2006) six recommended steps: familiarization with the data through multiple readings of the written accounts and interview transcript; initial coding; theme identification; theme grouping; theme definition; and the final report. I coded the texts using emergent codes that came from identifying central themes in the manifest (as opposed to latent) content rather than applying *a priori* codes generated from theories of change (Boyatzis, 1998).

There are three main categories in which these themes from the texts fall: (1) Relationships, (2) Organizations, and (3) Resources. Each category, in turn, has several associated themes. For example, among the Relational themes were the role of friendships, networks, collaborations, and mentoring (both formal and informal). These themes connect with prior work on change management around networks and strong ties that facilitate institutional change (Battilana & Casciaro, 2012, 2013). In the institutional and organizational category, professional organizations and societies, conferences, workshops, and publications were all common elements in the stories of changes in engineering ethics education that the trailblazers told. These themes help illustrate the trailblazers' status as institutional entrepreneurs – actors who create, modify, or diminish institutions through their own actions (Battilana, Leca, & Boxenbaum, 2009) – and thus connects to additional literature on change management. Finally, in the resource dependence section, the themes include pressures, rewards, and incentives. These themes relate to the literature around resource dependence theory and the effects of environmental resources as catalysts and mediating factors for change management (Hillman, Withers, & Collins, 2009).

Some themes in one category apply in other categories as well. The organization is intended to provide some structure to the larger conversation about common factors among the trailblazers' accounts. In addition to these categories, we observed that serendipity is a cross-cutting theme among several trailblazers' stories. As Martin pointed out in his chapter, there is an element of luck involved in these developments: the luck of being at the right party at the right time to establish key relationships (Davis); the luck of having another pair of scholars back out from their spot in an organization's workshop in order for another pair to attend (Martin); or the luck of a key resource, a tenure-track position, opening up in time (Johnson). While this is by definition difficult to anticipate, control, or plan for, happenstance has nonetheless shaped the stories that the authors describe.

The next sections briefly elaborate upon each of the three main thematic areas. In total, these groupings provide useful points of consideration for anyone interested in continuing to push the field of engineering ethics forward. Additionally, these observations also provide lessons for anyone interested in changing other areas of engineering education.

Relationships

The trailblazers all discussed guidance, generosity, and collaborations that enabled and augmented their own work to change the state of engineering ethics and ethics education. Through training and mentoring experiences, social, familial, and professional networks, and help from allies at critical moments, authors demonstrate the centrality of relationships to changemaking.

Training and mentoring

Nobody contributing to this volume initially trained in engineering ethics; thus, the stories of how these trailblazers received their formal and informal training is an important theme of both personal transformation and interpersonal connection. Three of the trailblazers studied engineering, eight studied philosophy, and one (Pinkus) studied history. A positive element of their minimal training in engineering ethics was the confluence of perspectives working on a similar problem – the meanings of engineering ethics. A second hopeful observation here worth remembering: formal training is not a prerequisite for an individual to become interested or active in teaching or researching engineering ethics. While absence of an engineering ethics background does not preclude participation, some form of formal or informal training and mentoring can help bridge disciplinary gaps. Vivian Weil and Robert Baum were two individuals whom several trailblazers cited as pivotal mentors to guide their own beginnings in engineering ethics. They and other mentors helped the trailblazers develop personally and professionally over their careers. These were deep personal transformations that often required years of sustained engagement in the community.

In addition to their own training, the trailblazers discussed programs to train and mentor future engineers and faculty members. These programs specifically focused on either undergraduates, graduate students, or faculty members. Although coursework is the most common example, other programs include Research Experience for Undergraduates, the NSF-funded Graduate Research Ethics Education workshops, and faculty development workshops such as those that Harris and Johnson initiated to train faculty members to teach engineering ethics in their own courses. While there have been programs in the past, both Hollander and Loui raise the important question of how to perpetuate such programs and train the next generations of engineering ethics educators. In her chapter, Hollander notes that "NSF programs made ethics a component of their solicitations, including the flagship program for interdisciplinary graduate science and engineering education, which began in 1998." How to train future generations remains an open question, but the themes in the trailblazers' stories suggest that the answer(s) will involve some combination of public and private funding, collaboration, incentives, and a little luck.

The influence of networks

Social, familial, organizational, and mentoring networks have played a large role in each of the trailblazers' work and careers. Many of the authors had mentors who guided their work and helped provide them opportunities. Robert Baum spent time as the NSF program director for the Ethics and Values in Science and Technology (EVIST) program from 1974-1976, and in his faculty role at Rensselaer Polytechnic Institute (RPI), he worked with Johnson as she began her career. Weil, on the other hand, helped mentor countless other faculty members across the country while she was on the faculty at Illinois Institute of Technology (IIT). While there, she also helped form (in 1987) and direct the Center for the Study of Ethics in the Professions at IIT. Hollander, a contributing author to this volume, is a third oft-cited mentor for many of the other trailblazers. In her various roles at NSF she helped guide projects, collaborations, and build new networks in the ethics community. As Pritchard tells the story, it was Hollander's suggestion to Michael Rabins, a mechanical engineering faculty member at Texas A&M University, that they consider working together given some overlapping interests. The result was their 1995 textbook with Harris (also at A&M) called *Engineering Ethics: Concepts and Cases* (C. E. Harris, Pritchard, & Rabins, 1995).

Along with networks of mentors, all of these trailblazers also had networks of collaborators. Formal programs and workshops helped shape and maintain some of these networks. For instance, there was a famous program that Baum ran from 1978-1980, supported by National Endowment for the Humanities (NEH), called the National Project on Philosophy and Engineering Ethics. The project helped philosopher-engineer teams to work on issues in engineering ethics. Several famous textbooks on engineering ethics came from that project, e.g., Martin and Schinzinger's *Ethics in Engineering* (1996) Shuman and Pinkus (with Hummon and Wolfe

(1997)), Luegenbiehl (with Clancy (2017)), and Mitcham (with Williams (1994)) all mentioned co-authored textbooks with collaborators in their chapters as well.

In order to maintain these collaborative networks over time, the trailblazers relied upon technology to facilitate communication, programs, and meetings (e.g., conferences, workshops). For example, when these collaborations first started, the US Postal Service helped geographically dispersed collaborators develop their ideas and writings. Indeed, while some of the authors mentioned working with colleagues at their own home institutions, they also worked with others across the United States — and in some cases across the globe — to help push the field forward. Johnson and Shuman each mentioned working with colleagues in Europe, especially the Netherlands. In the opposite cardinal direction, Luegenbiehl and Mitcham developed relationships with colleagues in Japan and China.

There were also a couple of family networks that lent a fortuitous boost to the trailblazers' work (harkening back to the prior mention of luck). For example, Pritchard read a book *Must Destruction be Our Destiny* in fifth grade by Harrison Brown — his mother's cousin — that may have planted the seed so that, as he said, "in the summer of 1979 perhaps I was ready to investigate ethics in engineering after all." This was an example of family connections having an impact early in one's life. Shuman, on the other hand, had family connections making an impact later in life. His sister-in-law, Phyllis Kayten, worked for the National Transportation Safety Board (NTSB), and, together with her father, they were able to offer Shuman valuable insights and documents for his project with Pinkus on the Challenger explosion. Whether it was fortuitous family relations, partnerships formed by happenstance, or auspicious timing, luck was a common theme in many of the stories about changes in engineering ethics education.

Allies abound

Along with direct support from collaboration networks and mentors, there was also help from allies — people indirectly associated with the engineering ethics community who were in positions to assist people more directly involved in the community. Despite their peripheral connection, these allies had the power and opportunity to stymie or bolster engineering ethics education. The list of allies includes Deans, other faculty members in engineering and philosophy, and private donors. These were people with access to resources or decision-making power who lowered the barriers to entry for some of these projects that the authors describe to gain momentum.

It is one thing for someone to actively promote or teach engineering ethics, but it is another, nontrivial, thing to help those who are actively engaged in that activity.

At Texas A&M University, for example, Harris credits a sympathetic Dean as one of the reasons for expanding the engineering ethics course taught to senior engineering students. A second example is other faculty members in engineering (or philosophy) – Davis worked with mechanical engineerings at IIT and Harris worked with other civil engineering faculty members at Texas A&M University. A third example is the leaders of other organizations such as the National Academy of Engineering (NAE). Hollander describes how William Wulf, during his presidency at NAE, helped sponsor a large conference in 2004 to consider the macroethical implications of engineering and technology. Wulf also worked with Caroline Whitbeck to transfer her online ethics center over to the NAE's auspices and the Harry Bovay to create the Center for Engineering Ethics in Society in 2007. In short, Wulf was a valuable ally within the Academy.

Outside of academia, Martin mentions another ally: professionals in industry. He recounts working with Carl Skooglund at Texas Instruments (TI). At TI, Skooglund developed several programs and workshops on corporate and professional ethics. Skooglund also provided support and feedback to Martin and Schinzinger in their own work.

There is also the negative case of allies to consider – what might happen in the *absence* of these networks and allies? Mitcham discusses this experience in his account. He cites the lack of these interpersonal resources as a reason that efforts to introduce engineering across the curriculum at his university were unsuccessful. In his own words: "The bottom line is that I failed to make the kind of diplomatic alliances with the international political economy program and other campus efforts that would have enabled success. There were numerous missed opportunities."

Overall, the trailblazers' accounts paint a compelling picture of the salutary effects that interpersonal relationships can have when working toward systemic change. Of course, there were other aspects contributing to the changes over the past 50 years.

Organizations

Organizations form a second group of themes that are common to the trailblazers' experiences of change. Within this category are publication venues, professional societies. We will look at each in turn.

Spreading the word

Ideas need vectors to travel. The creation of new venues for idea-sharing, both in face-to-face meetings and in publications, including newsletters, journals, case study materials, textbooks, and scholarly books, were a common element in the trailblazers' stories.

Herkert, for example, mentions having Davis critique some of his work, which simultaneously conveyed a feeling of having really 'made it'. As mentioned in the discussion about collaboration networks, some of the trailblazers co-authored textbooks. Others helped form journals like *Business and Professional Ethics*. Many of them also published scholarly books on engineering ethics in the course of their careers, including Davis, Johnson, and Mitcham.

Although the trailblazers also mentioned private correspondence (originally by postal service and then by email as time passed), public archival conversations were frequently cited as important for establishing engineering ethics as an area of scholarship, promoting exchange and advancement of ideas, and furthering the academic careers of the trailblazers.

Organizing structures

The second theme in this category is the assistance provided by organizations outside of universities that have affected the development of the field of engineering ethics over time. Engineering professional societies, such as IEEE, NSPE, or ASCE, have facilitated conversations among academic engineers, practitioners, and industry. They adopt, amend, and enforce professional codes of ethics to which their members are expected to adhere. Other focused academic societies create spaces for historical examinations of normative aspects of engineering (Society for the History of Technology (SHOT)), philosophy, engineering and technology (PET), or examinations of applied and professional ethics (APPE). There are other non-profit organizations (aside from the ones listed) like the National Institute for Engineering Ethics (NIEE) and the Hastings Center that seek to advance inquiry and education around engineering ethics topics. The National Academies are a non-governmental institution that advises the nation on matters related to science and technology, including ethical issues. Finally, there are governmental organizations like NSF, NEH, and NAE (a private non-profit chartered by the government) that fund research and education projects related to engineering ethics, and the National Academies, . The key idea here is organizations can aid change agents by providing support and avenues to advance knowledge or reach a broader audience. Organizational endorsement or leadership on key initiatives can amplify engineering ethics education efforts dramatically. On the flip side, without organizational amplification, it can be difficult to achieve change at scale. efforts can hit a wall and stall quickly.

Influences from the ethics of other professions

The institutions established from professional ethics in medicine, business, and law also drove some of the trailblazers' interests and early work, informing how some of these authors thought of engineering ethics. Weil (1984) further corroborates this influence from law and medicine in her article on the rise of engineering ethics. The shift in professional domains suggests that many ideas in engineering ethics were not necessarily *de novo* creations. As Martin described it, "Medical ethics became a model for what might be possible in other branches of professional ethics." It is no surprise therefore that one of the trailblazers – Rosa Lynn Pinkus – had a background in medical ethics. Davis, on the other hand, came from legal ethics. In his own words, "Much of what I have done in engineering ethics is to translate what I learned about professional ethics from lawyers. That may explain why much of what I have had to say about engineering ethics seemed novel. As far as I know, no one else reached engineering ethics through legal ethics." Finally, Luegenbiehl brought experience in business ethics. He describes his experience combining engineering and business ethics in a course: "There were texts available for the business ethics portion of the course, but nothing of a similar nature for engineering." Experiences with these other professions provided these trailblazers perspectives to think about engineering as a profession, its standards of conduct, and how to teach that material to students.

The influence from business, medical, and legal ethics also highlights the interdisciplinary nature of engineering ethics as an amalgamation of other traditions. None of the trailblazers trained in engineering ethics as a graduate student. This meant that as the field was growing it was receiving contributions from myriad other places and depending on precedents in other areas for inspiration in engineering. Ultimately a wide variety of sources and factors that have shaped developments in engineering ethics and engineering ethics education.

Resources

Our trailblazers' accounts further reveal the ways in which their efforts in engineering ethics education were shaped by numerous rewards, incentives, pressures, and costs operating at local, national, and global levels. . Resources enabled crucial activities in the field, e.g, research (supporting academic careers and keeping faculty members engaged in ethics-related work), workshops (training future faculty members, growing the community), and collaborative textbook and case study writing (providing some of the pedagogical material to help train future engineers in ethical decision-making).

Rewards and incentives

Many of the authors cited access to resources, broadly construed, as facilitating factors that enabled their efforts to advance the field of engineering ethics and engineering ethics education. These resources came from both public and private sources. The funding helped fuel research projects, training programs, workshops, educational materials, and distinguished lectures, among other things. The most prominent public source was the National Science Foundation. Programs like Ethics and Values in Science and Technology (EVIST), which later became Ethics and Values in Society, funded workshops and research throughout the 1970s and 1980s (Hollander & Steneck, 1990), and almost every trailblazer mentioned receiving NSF funding as important for enabling their work in engineering ethics. The NEH was another example of public funding mentioned in most stories, most notably supporting the National Project on Philosophy and Engineering Ethics.

The private funding sources came from industry, foundations, and individual philanthropy. For example, Davis mentions the Exxon Foundation sponsoring a grant to create ethics modules in the mid-1980s. Similarly, the Engineering Foundation supported Loui's recorded lectures on engineering ethics, which eventually were posted online as a free resource for anyone to view. Along with foundation, professional societies, and corporate funding, there was also an individual private donor, Harry Bovay, who created a lecture series and endowed chair, thereby literally ensconcing someone in the space of engineering ethics at Texas A&M University and Cornell University. Going forward, it may behoove the engineering ethics community to continue identifying private funding sources to spur continued activity in the field, especially as pressures on faculty members' time and energy continue to accumulate.

Pressures

Ironically, just as a set of pressures can lead an engineer to unethical behavior, there was a set of pressures driving some of these individual and group efforts to advance meanings and practice in engineering ethics and education. Some of these included the pressure to publish, the pressure to receive external funding, and the pressure to build a career or carve a niche of expertise. Even with all the necessary ingredients in place, the essential actions and reactions to advance engineering ethics and engineering ethics education may not proceed expeditiously without a catalyst to set things in motion.

For example, consider tenure and the requisite activities to earn academic promotion. The authors may have had interests in some of these issues around professional engineering — whistleblowing, loyalty, codes of ethics — but the pressures to publish in order to earn tenure helped instigate some of their efforts. As Davis said, he wrote reports on workshops because "Vivian was trying to polish [his] record in the hope that [he] might one day get tenured". As Martin writes, "academics cannot sustain their investments in a field without...opportunities to publish". Some of these individuals may have wanted to continue working and developing this field, but without the combination of pressures to write as well as opportunities to publish their work — an opportunity more widely available with more outlets like *Business and Professional Ethics* or *Science and Engineering Ethics* — then they might have left their engineering ethics work in search of more viable options. This suggests not only that publication pressures moved people toward progress but also that publication outlets were another catalyst to lower the barriers to activity in the area of engineering ethics.

At the same time, pressures from traditional scholarly communities in both engineering and philosophy also acted as barriers to these achievements, particularly in failing to properly acknowledge or reward interdisciplinary work. This tendency of academic silos to isolate individual scholars pursuing interdisciplinary work like engineering ethics education underscores the importance of relationships and organizations in supporting scholars and providing pathways for reception of work that is not always readily accepted.

Funding was a third pressure that propelled activity in the field. For example, the availability (or occasional lack thereof) of funding opportunities from NSF shifted scholars' activities and attention. Shuman describes the effects of policy shifts during Reagan administration driving him toward new projects and away from his research on medical services systems. In particular, NSF's support for social and behavioral science research was eliminated (D. Johnson, 1992), resulting in fewer grant opportunities. Needing to support his scholarly activities, Shuman pivoted toward new avenues for scholarship ultimately finding engineering ethics and engineering education research.

The pressure to teach meaningful content effectively was a final pressure that almost all of the trailblazers mentioned. The classroom was a place where these faculty members could influence future generations not only through their writing but also through direct interaction with people training to be engineers. There was especially a pressure, as Johnson put it, "to figure out how to teach philosophy and ethics to students that really weren't very interested in it". The trailblazers needed to find ways to teach the material to potentially disinterested or skeptical (as Harris described it) students, thereby creating pressure to innovate in the classroom and create subsequent changes to the state of engineering ethics education at their respective universities. Where successful, these interactions have perhaps some of the highest potential for impact, changing lives. For example, Shuman recounts one of his students writing to him seven years after taking his engineering ethics course to describe the impact of the engineering ethics course while working as an engineer: "That course was one of the better experiences I had during my curriculum and one that I feel I continue to get more from as I move along my career. " In total, these pressures can be effective ways to instigate change.

Concluding Remarks

The constellation of actors, organizations, resources, and happenstance has created an ecosystem in which engineering ethics education developed over the past 50 years. Any effort to understand the current state of engineering ethics education in the United States, and chart a course for future improvement, must first account for how we got here. There were communities. There was immense generosity of time and assistance. There were healthy debates within and outside of the academy. There were new and growing opportunities to publish. There were textbooks and case studies. There were professional organizations thinking about their roles and those of their member engineers in society. There were academic societies focused specifically on engineering philosophy and professional ethics. There were unforeseen and preventable accidents providing a clarion call to action. There were funding opportunities, pressure to teach, avenues for career advancement, and a desire to help engineers understand the meaning of engineering ethics that helped to drive the trailblazers to act. Thinking about these factors, and others, in unison provides a dynamic picture of engineering ethics education rather than a static one in which change can seem more formidable. When thinking about the state of ethics education in the United States, either past, present, or future, one must necessarily consider how these elements are interacting with each other to produce moments of inertia and/or change.

Even after identifying these themes, however, there still exist open questions for the engineering ethics community to address. Loui provides a litany of such questions at the end of his chapter. One of the critical ones on our minds is: how can the community continue to grow? Is there a carrying capacity limiting the size or rate of growth, and if so, how might our ecosystem become more hospitable to engineering ethics educators? Much has been done, and there is still work to do. Hopefully the experiences, insights, successes, and failures of the trailblazers can help smooth the path for those who follow, and the broader engineering community can come to think yet more deeply about ethical decision-making in engineering and how engineers learn about it.

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CHAPTER 3: FACULTY MEMBERS' MENTAL MODELS OF ENGINEERING ETHICS EDUCATION

Preface

Background

Despite its importance in the engineering curriculum, there is large variation in the quantity and quality of engineering ethics education in undergraduate engineering programs in the United States. This raises the question of the role that faculty members play in creating and propagating that state of affairs.

Purpose

To understand some factors contributing to this state, this study focused on characterizing faculty member mental models of engineering ethics education

Design

A mental models methodology was used for this study. Semi-structured interviews were conducted with 25 faculty members from civil, electrical, and mechanical engineering at 21 different universities to explore how faculty members internally represent the state, form, function, and purpose(s) of the postsecondary engineering ethics education system(s) in the United States.

Results

Faculty members exhibited multifaceted mental models that likely derive from a combination of their institutional environments and prior educational and work experiences.

Conclusions

Efforts to improve the state of engineering ethics education should be cognizant of different mental models of engineering ethics education. These model typologies and characterization will assist work to develop faculty mental models and suggest different strategies that work for developing particular mental models.

Keywords: faculty members; mental models; engineering ethics education

Introduction

According to sources ranging from the National Academy of Engineering (NAE, 2005, pp. 132, 166) to the Accreditation Board for Engineering and Technology (ABET) and its predecessor organization the Engineers' Council for Professional Development (ECPD) [1977], engineering ethics education is an important element of undergraduate engineering education.

Engineers work in sundry sectors and contexts. In their practice, engineers make myriad decisions, and sometimes those decisions can involve ethical dilemmas. One cannot assume nor take for granted that all engineers will have a priori knowledge about navigating those decisions; hence engineering ethics education is important. To communicate this importance, consider two statements from major national organizations in the engineering field – the American Society for Engineering Education (ASEE) and the National Society of Professional Engineers (NSPE). First, consider part of the ASEE statement:

> ASEE agrees that ethics education must be an essential element in the education of all engineers...To educate students to cope with ethical problems, the first task of the teacher is to make students aware of ethical problems and help them learn to recognize them. A second task is to help students understand that their projects affect people for good or ill, and that, as "moral agents" they need to understand and anticipate these effects. A third task is to help students see that, as moral agents, they are responsible for helping to develop solutions to the ethical problems they encounter. (ASEE, 1999)

Here, not only is ASEE endorsing a strong prioritization of engineering ethics education, but it is also highlighting the central role of faculty members in making this come to fruition. Undoubtedly this is a student-focused enterprise with outcomes specific to the students, but the process never leaves the ground without intentional faculty member effort. This does not mean faculty members have to provide explicit lectures pertaining to engineering ethics, but they do need to conscientiously incorporate something about engineering ethics into their courses in order to achieve the goals of engineering ethics education. The NSPE statement envisions ethics considerations as more ensconced in concerns of professionalism, but it once again places the onus of instruction on engineering faculty members:

> The National Society of Professional Engineers strongly believes that engineering curricula should incorporate instruction designed to instill engineering students with professional concepts. Although a specific course may or may not be provided for this purpose, bringing

> professional concepts to the attention of the student should be a responsibility of **all engineering faculty** [emphasis added]. (NSPE, 2015)

Before becoming professional engineers, most of these individuals studied engineering at a postsecondary institution. In the United States, over 90,000 students graduate with a bachelor's degree in engineering every year (NCES, 2016). Most of these engineers educated in the United States obtain their degrees from an engineering program accredited by ABET (Yoder, 2016). As part of ABET's engineering accreditation standards for student outcomes, criterion 3.4 dictates that engineering graduates must have

> an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts (ABET, 2019).

These criteria establish a bare minimum for a program to earn ABET accreditation, and are simply another sign of the importance of engineering ethics education. In total, statements from organizations like ASEE, NSPE, and ABET support the notion that engineering ethics education is an important element of engineering education.

Even though ethics education is important, statements like the preceding ones leave open questions of how students should learn engineering ethics and how faculty members should teach engineering ethics. Indeed, despite this stated importance, engineering ethics appears heterogeneously in undergraduate engineering programs in the United States. One can readily observe that some faculty members do teach engineering ethics in their courses while others do not. Given the central role that faculty members occupy in making decisions about the undergraduate curriculum writ large and the extent to which ethics appears in their classrooms, more specifically, one way to understand the state of engineering ethics education in US engineering programs is to study engineering faculty members. What influences their decision making regarding engineering ethics education? What beliefs and values do they hold about engineering ethics education? What factors do they perceive as influencing their behavior? Characterizing faculty members' mental models – internal representations of systems and process (Philip N. Johnson-Laird, 1983; Khemlani, Barbey, & Johnson-Laird, 2014; Morgan, Fischhoff, Bostrom, & Atman, 2002; Rouse & Morris, 1986) – of engineering ethics education can help us address these questions. The underlying premise is that different mental models may manifest different curricular and pedagogical decisions from faculty members.

Background

There is a long-standing perception that the average engineering ethics education that students receive is inadequate (Bucciarelli, 2008; Conlon & Zandvoort, 2010; Herkert, 2000; Hess, Beever, Strobel, & Brightman, 2017). While the average may leave room for improvement, there are pockets of progress (NAE, 2016), so it is not a uniformly dire landscape. One of the basic questions driving this research focuses on the differences in engineering ethics education that students receive. This has led to a focus on faculty members since they tend to make key decisions about course content and instructional processes. Despite research suggesting that over 90% of employers agree that an understanding of ethical and professional responsibility is important (Lattuca, Terenzini, & Volkwein, 2006), engineering faculty often do not teach ethics in their courses, offering numerous reasons for not doing so – e.g., a lack of time in the curriculum, lack of training to teach it, or lack of incentives to teach it (Canney et al., 2017; Walczak et al., 2010).

Starting with the observation that some faculty teach engineering ethics in their courses while others do not (Colby & Sullivan, 2008; Haws, 2001; Stephan, 1999) – and those who do teach it vary in their pedagogical approaches (Bairaktarova & Woodcock, 2015; Davis, 2006; Graber & Pionke, 2006; Haws, 2001; Herkert, 2000; Loui, 2005), attitudes, beliefs, and motivations – one question arises: what are the differences among groups of faculty members in their perspectives toward ethics education? This study addresses the gap in understanding faculty members' internal models of engineering ethics education by characterizing their mental models – internal representations of systems and process (Philip N. Johnson-Laird, 1983; Khemlani et al., 2014; Morgan et al., 2002; Rouse & Morris, 1986) – of engineering ethics education. This work assumes the following premise: different mental models inform faculty curricular choices, which manifest as differential pedagogies and curricula of engineering ethics in engineering courses. The variety in observed behavior regarding ethics education suggests that there may also be a variety of ways in which faculty members conceive of engineering ethics education, their surrounding educational contexts, and influential factors affecting their classroom choices.

The present study is designed to explore the potential space of mental models. By "space of mental models" we mean the range of internal representations of the engineering ethics education system that a faculty member may have. The meaning of this construct is discussed in the literature review section. Meaningful statistical claims are not the objective of the present qualitative study, but the results do identify common themes to investigate in future work. For example, future work can correlate those mental models or specific entities or areas within the models with the degree to which engineering faculty members report themselves to cover engineering ethics content in their courses and/or other institutional factors mentioned above.

In addition to fueling future research, identifying gaps between the prevalent mental models in discrete faculty groups may reveal key differences to target for future faculty development and interventions. The ultimate goal is an improved undergraduate engineering ethics education and capacity for ethical decision-making among practicing engineers. The information will also help shape understandings about the state of engineering ethics education and engineering education more generally insofar as the same decision-making logics affect more than just ethics education decisions.

Literature Review

This study revolves around faculty members' mental models of engineering ethics education with the idea that those mental models inform curricular and pedagogical decisions. Therefore, the following literature review covers three areas: engineering ethics education, faculty decision-making, and mental models.

Engineering ethics education research

Research on engineering ethics in undergraduate programs has approached the topic from myriad perspectives, as outlined in Barry and Herkert's chapter on engineering ethics in the *Cambridge Handbook of Engineering Education Research* (Barry & Herkert, 2014). One branch of work has approached it from the student perspective, ranging from an investigation on student perspectives toward ethics and professional identity (Loui, 2005) to a more tangential approach looking at students' views toward social responsibility (Canney & Bielefeldt, 2015; Lathem, Neumann, & Hayden, 2011). A separate branch has also looked at this topic from the recent graduate's perspectives and encounters with ethical dilemmas as a practicing engineer (Angela R. Bielefeldt & Canney, 2016; McCaul, Whitlatch, & Gustafson, 2003).

From the teaching and learning side, one branch of research in engineering ethics education has looked at methods for assessing ethics-related student outcomes. Some of this focuses on ABET student learning outcomes while others extend beyond ABET (Self & Ellison, 1998; Shuman, Besterfield-Sacre, & McGourty, 2005; Sindelar et al., 2003). Another branch questions which method of teaching engineering ethics may be most effective and offers different pedagogical approaches (Bairaktarova & Woodcock, 2015; Cruz & Frey, 2003; Davis, 2006; Graber & Pionke, 2006; Haws, 2001; Herkert, 2000; Loui, 2005). A third branch looks at specific issues within engineering ethics and the classroom. With this research on students and teaching, there is still a question about engineering ethics education and faculty members.

To date, there has been less work in engineering ethics that focuses on the faculty member perspective. Such work that does exist tends to analyze: how faculty and departments teach engineering ethics in specific contexts – e.g., case studies, ethical theory readings, reviewing profession codes (Colby & Sullivan, 2008); how faculty members generically make pedagogical decisions (Tuana, Wisw, Christman, Lau, & Litzinger, 2003); different programs that facilitate engineering ethics education (Burack, Duffy, Melchior, & Morgan, 2008); the role of a sense of moral agency in engineering education (Whitbeck, 1995); comparisons of content between engineering, health, business, and legal ethics courses (Barry & Ohland, 2009); specific issues limited to academic integrity (Liu et al., 2015); and what lies within the bounds of engineering ethics (Herkert, 2005). However, an important piece in the engineering education equation, faculty attitudes and beliefs, has received comparatively less attention. To wit, there currently exist gaps in the literature on faculty perspectives of engineering ethics education.

The extant literature on engineering faculty views on engineering ethics has tended to be limited in scope and specific to certain engineering disciplines. For example, the research may indirectly investigate the influence of prior industry experience on faculty views of a variety of work life issues, including ethics (Magnell, Geschwind, Gumaelius, & Kolmos, 2014), focus on comparing faculty and students' views of what constitutes a problem that possesses an ethics-specific dimension (Holsapple, Carpenter, Sutkus, Finelli, & Harding, 2012), or study faculty member views of macroethics (Canney et al., 2017). While these studies certainly touch issues that affect the state of engineering ethics education, none of them directly addresses the state of engineering ethics education writ large, either from the individual faculty member perspective or the structural/system perspective. The problem is simply stated: we understand pieces of how faculty members make decisions in general, but we do not understand how this manifests for something specific like engineering ethics and the background views that faculty members have that inform their decisions. This gap in understanding how the confluence of faculty-centric and program-centric factors can shape pedagogy and curricula of engineering ethics education is the area that the current study addresses.

Canney et al. (2017) have come close to addressing this gap in their study on faculty views of macroethical engineering education, but their study design – interviewing faculty members to understand how they viewed macroethical issues in engineering – was restricted to a particular aspect of engineering ethics education. Katz and Knight (2017) similarly approached the realm of answering this question by using survey data from over 1,200 faculty members to study factors associated with faculty member beliefs, but that quantitative study also suffered from design restrictions. The study suggested places where ethics most commonly occurs in curricula (i.e., the first-year engineering course and senior capstone course) and that work experience is positively correlated with a likelihood that they teach ethics in their courses. The study left open the question of faculty members' cognitive processes that led to those results in the study. Although these studies focused on faculty members and engineering ethics education, neither adopted a mental models approach. In short, despite the importance of faculty member decision-making in the education process, there do not exist many studies investigating faculty member mental models of engineering ethics education.

Faculty decision-making

Since there is evidence to suggest that Academic discipline can strongly influence professional and curricular decisions (Katz & Knight, 2017; Lattuca, Terenzini, Harper, & Yin, 2009; Smart, Feldman, & Ethington, 2000), it may be important to study engineering faculty members in multiple disciplines for a study of faculty members' mental models in order to fully characterize the space of mental models of engineering ethics education. Other factors noted in the literature that affect engineering faculty member curricular decisions are time, personal values such as family responsibility, and preparing students for the needs of industry (Huang, Yellin, & Turns, 2007). Among faculty of different ranks and genders, faculty members also allocate their time differently to teaching, research, and service (Link, Swann, & Bozeman, 2008). Personal faculty judgments are further affected by institutional constraints as well as personal affective orientations, beliefs, and experiences (Shavelson & Stern, 1981). Kagan (1992) defines teacher beliefs as "tacit, often unconsciously held assumptions about students, classrooms, and the academic material to be taught." The point here is to emphasize the potential interactions between faculty member mental models and curricular outcomes, e.g., engineering ethics education, as potentially mediated by these additional factors. Table 2 lists some of these factors, organized by whether the factor originates in the faculty member, the university, or something outside the university. These factors are reflected in Lattuca and Stark's (2009) academic plan model. The model illustrates the different elements inside and outside of a university that can affect the plan for a course – what it is taught, how and why.

Table 2. Factors affecting faculty decision-making.

Factor locus	Factor	Noted effects	Relevant literature
Internal to faculty member	Beliefs about student learning and cognition	Teaching orientation (student-centered vs teacher-centered; deep vs shallow approach)	(Emil & Cress, 2014; Hativa & Goodyear, 2002; Kember & Gow, 1994; McKenna, Yalvac, & Light, 2009; Stark, 2000; Stes, Min-Leliveld, Gijbels, & Van Petegem, 2010)
	Personal beliefs about knowledge	Effects on research Project choice	(Hativa & Goodyear, 2002; Montfort, Brown, & Shinew, 2014)
	Beliefs about instructional purpose	Teacher-centered vs. learner-centered	(Martin, Prosser, Trigwell, Ramsden, & Benjamin, 2000)
	Prior educational experiences	Course planning intentions and exercises	(Fairweather, 1993; Stark, 2000)
	Prior and current work experiences/roles	More open to including certain experiences (including ethics)	(Demery, Brawner, & Serow, 1999; Magnell et al., 2014)
	Time	Decisions strive for satisficing	(Fairweather & Beach, 2002; Huang et al., 2007)

Table 2 continued

	Teaching goals and motivation	Affects pedagogical and curricular choices	(Lattuca & Stark, 1994; Matusovich, Paretti, McNair, & Hixson, 2014; Nespor, 1987; Stark, 2000)
	Exposure to research in SToL	More likely to choose student-center approaches	(Borrego & Henderson, 2014; Grady, Rozas, & Bledsoe, 2010)
	Career stage	Early, middle, and late differentiates time allocation choices	(Baldwin, Lunceford, & Vanderlinden, 2005)
	Demographic characteristics	Female faculty allocate more time toward university service than men	(Link et al., 2008; O'Meara & Campbell, 2011)
Internal to university	Reward structures	Time allotted to teaching Dissonance with personal priorities Affect extrinsic and intrinsic motivation	(Austin & Gamson, 1983; Berman & Skeff, 1988; Blackburn, Bieber, Lawrence, & Trautvetter, 1991; Ernst, 1995; Fairweather, 1993; Lee, Castella, & Middleton, 1997)
	Departmental affiliation	Affects decision to engage in SoTL	(A. R. Bielefeldt, 2015; Lattuca & Stark, 1994; Lindblom-Ylänne, Trigwell, Nevgi, & Ashwin, 2006; Smart & Elton, 1975; Stark, Lowther, Sharp, & Arnold, 1997)
	Departmental Environment	Prioritizing research, teaching, or both	(Fairweather, 2002)
	University type	Correlated with interests and expectations in teaching, research, and service	(Blackburn et al., 1991; Harper & Lattuca, 2010)

Table 2 continued

External to university	Accreditation standards	Changes in curricular content to satisfy external standards	(Lattuca et al., 2006; Stark, 2000)
	Differentiated status in society	Striving to improve university's reputation leads to mission creep and tailoring work to fit funding agendas	(Gonzales, 2012)
	Notably absent: decision-making as function of teacher-perceived responsibility (to the greater community, though they might perceive their research efforts as their mechanism for fulfilling social obligations)		

Mental models

What are mental models?

Mental models are the modality by which humans describe, explain, and predict a system's form, state, function, and purpose (Rouse & Morris, 1986). They are cognitive models that facilitate deductive, inductive, and abductive reasoning in order to enable prediction and continuous navigation of the material world (Philip N. Johnson-Laird, 2005). Mental models basically permit their users to engage in planning and develop expectations of potential future actions, as determined by mental experimentations (Carley & Palmquist, 1992; Wickens & Kramer, 1985). According to the theory, mental models allow for more flexibility in an individual's reasoning than concepts, schemes, or scripts (Holland, Holyoak, Nisbett, & Thagard, 1996). Moreover, some speculate that mental models could even transcend individuals, which leads to the idea of shared mental models that could help explain collective decision-making and joint views of the world (Denzau & North, 1994). From a modeling perspective, they represent a many-to-one mapping from external reality to the mental model itself (Moray, 1996).

The associated mental models methodology captures pooled beliefs of disparate groups, creates representative models from these beliefs, highlights gaps between the characterized models via comparison, and identifies areas upon which to build future knowledge (Morgan et al., 2002). These models do not simply self-assemble fully formed in a stochastic quantum leap; rather, they are dynamically, incrementally, and socially constructed from intrapersonal and interpersonal experiences (Patricia H. Werhane, Hartman, Archer, Englehardt, & Pritchard, 2013, p. 25).

Mental models research

Potential study designs for characterizing mental models include semi-structured or open-ended interviews coupled with questionnaires (Morgan et al., 2002), textual analysis (Carley, 1997), and a process of extracting concepts, relationships, statements, and map creation (Carley & Palmquist, 1992). The general method still leaves open questions about model stability and tractability (Doyle & Ford, 1998).

Mental models have been studied in various fields of research. In system dynamics, they have been used to study large industrial processes (Daniels, de Chernatony, & Johnson, 1995) and climate change (Doyle & Ford, 1998; Ford & Sterman, 1998; Sterman & Sweeney, 2007). In cognitive psychology, mental models have been used to study human reasoning processes and understanding (Hinterecker, Knauff, & Johnson-Laird, 2016; P. N. Johnson-Laird, 2006; Philip N. Johnson-Laird, 2010; Khemlani et al., 2014). In risk communication, the mental models approach has been used to identify gaps among expert mental models and an average person's mental model of a process or chemical exposure (Bostrom, Fischhoff, & Morgan, 1992; Morgan et al., 2002; Sterman, 2008). In the area of team dynamics, the mental models approach has helped researchers identify how quickly teams converge on a shared mental model and how that affects their decision-making processes (Lim & Klein, 2006; Mathieu, Heffner, Goodwin, Salas, & Cannon-Bowers, 2000; McComb, Kennedy, Perryman, Warner, & Letsky, 2010). Finally, the mental models approach has been used in education to study topics like student learning and understanding in general (Gentner & Stevens, 1983; Mason-Mason & Tessmer, 2000; Seel, 2006) and specific topics like chemical equilibrium (Chiu, Chou, & Liu, 2002) and atomic structure (Harrison & Treagust, 1996).

Mental models in engineering education

In engineering education, the mental models method has been used to study both students and teachers. Given how often engineering students and engineers learn about and manipulate systems, the mental models method could be an advantageous method for research learning and decision-making in engineering. In other words, the mental models method presents an exciting opportunity for the engineering education research community, and the present study offers another demonstration of the method's applicability.

On the student side, the mental models method has been used to study recent application in engineering education for studying student sense-making (Brock et al., 2008), innovation (Fisher, Nair, & Biviji, 2014), and creativity (Mumford et al., 2012). It has also been used to study student understanding of thermal equilibrium (Fazio, Battaglia, & Di Paola, 2013) and concepts in electrodynamics (Carnes & Diefes-Dux, 2013). The method can also be used to study gaps between experts and novices in a particular technical area (Hsu, 2006).

In theory, any scenario in engineering education that involves individuals embedded in or operating on a system or process could use this method. Although this may be true, studies of teacher mental models, such as McMahon's (2012) study of teacher mental models of engineering design processes, are less common than mental model studies of students. Nonetheless, the current research on faculty member mental models assumes that different mental models inform faculty curricular choices, which manifest as differential pedagogies and curricula of engineering ethics in engineering courses. That assumption and the extant literature leads to the following research question.

Research Question

This study addresses the research question: *what are some of the mental models of engineering ethics education that faculty members in civil, mechanical, and electrical engineering have*? These disciplines were chosen for their relative representativeness of different ends of the spectrum regarding engineering ethics education, as suggested by prior research (Katz and Knight, 2017).

Research Worldview

For this study, I adopted a constructivist philosophical worldview because of the nature of the research question and method selection. Constructivism as a worldview acknowledges the socially constructed aspects of our lives that arise from interpersonal interactions (Gall, Borg, & Gall, 1996, p. 21). This worldview differentiates between physical reality and social reality, with the latter being the subject of the present inquiry. With a constructivist outlook, it is important for researchers to engage in reflexive consideration of their own role(s) in the scenario and mutual constructing of that reality under investigation (Gall et al., 1996, p. 24); we are inexorably operating concurrently in the same space as the participants. That linkage between researcher and participant consequently renders everyone participants, and thus the ultimate product of the research is a mutually constructed product from everyone involved (Guba & Lincoln, 1994, p. 111). The upshot in the current study is a more overt role of the researcher in the project in comparison with other worldviews, e.g., positivist, post-positivist.

Methods

I used a modified mental models method for this study (Bostrom et al., 1992; Morgan et al., 2002). This method is designed specifically for investigating a person's mental model of a system. The modification came in the analysis phase where I substituted model areas and a typology in lieu influence diagrams. Since this is an exploratory study designed to investigate the overall landscape of potential mental models, I am using these interviews as a way to characterize the space of possibilities that can exist among individuals faculty members. I am not suggesting which models may be more prevalent. I am not suggesting that particular mental models necessarily lead to certain pedagogical or curricular decisions. I also am not suggesting that these are shared mental models among a group of faculty members. While each of those may be exciting to explore in future work, they are not part of the current project. Instead, this study is about possibilities among individual faculty members as a way to understand how their decision-making processes. Although I do aggregate the models together for the sake of organizing the results, this is a different project than one that characterizes team or share mental models. To reiterate, the overall goal in this study to facilitate our understanding of an individual faculty member's mental model of engineering ethics education *by first mapping out the space of potential models*. I discuss this mapping process in the following sections that describe my data collection and data analysis.

Data collection

Data were collected from 25 faculty members in civil, mechanical, and electrical engineering departments across the United States. The following sections first describe the sampling and recruitment procedure as well as demographic data about the participants. A review of the interview protocol follows.

Sampling, recruitment, and participant demographics.

In the study's initial conception, I considered purposive selection of faculty members who teach engineering ethics and those who do not teach the topic in an attempt to dichotomize the sample population; however, as the study design developed, it became apparent that such a bifurcation would be too rigid. Thus, a more appropriate strategy was to avoid *a priori* categorization and purposive sampling of faculty members in favor of self-categorization from the participants as part of their interview. Conducting the study in this manner avoided the task of demarcating a bright line between what constitutes teaching engineering ethics. Likewise, it allowed for more nuance in *how much* participants reported teaching engineering ethics rather than a simple binary.

In lieu of purposive sampling, a maximum variation sampling method (Palinkas et al., 2015) coupled with snowball sampling – asking participants for recommendations of potential colleagues in their department who may also be able to participate in the study (Biernacki & Waldorf, 1981) – were used for participant recruitment. The combination of these sampling strategies supported the study's goal of mapping the space of potential faculty member mental models of engineering ethics education.

Participants were recruited using ASEE email lists for civil engineering, electrical engineering, engineering and public policy, and engineering ethics. The mechanical engineering division declined a request to send a recruitment email, citing division policy. Additional participants were recruited using recommendations from in-sample participants. Specifically, after interviewing a participant, I asked if they knew anyone else in their department or university who also may be interested in participating. This snowball sampling was done in an attempt to pair the participants with someone else from the same university and have university (or department) pairs in the data. Intradepartmental variation will be an item of interest in future work informed by this initial qualitative study.

Before recruitment began, the goal study sample size was $N > 24$ since that size allows for a high degree of conceptual saturation after which each additional interview yields a diminishing amount of information (i.e. diminishing marginal information) (Morgan et al., 2002, p. 76). In total, I conducted and recorded 25 interviews remotely using Internet-based technologies. The 25 participants were faculty members of various ranks in three different engineering disciplines – electrical, mechanical, and civil engineering. These three disciplines were chosen in order to provide a broad range of attitudes about engineering ethics education since there is evidence to suggest that differences exist in faculty member perspectives of engineering ethics across these disciplines (Katz and Knight, 2017). The participants also came from a range of university types – small, large, public, private, religiously-affiliated, doctoral-granting.

The tables and figures below present additional demographic information about the participants and schools represented in the study. The sample has a gender distribution representative of the faculty composition in engineering departments, as shown in Figure 6 and Table 3. Participants also ranged across years of work experience (Figure 7, Table 4), rank (Figure 8, Table 5), and census division (Figure 9, Table 6). Figure 10 further shows the geographic distribution of participants in the study (as measured by the location of their home university). This diversity in participants is the result of the maximum variation sampling approach that I employed.

Table 3. Participant gender and department affiliation counts.

	Mechanical	Civil	Electrical
Male	4	7	5
Female	2	4	3
Total	6	11	8

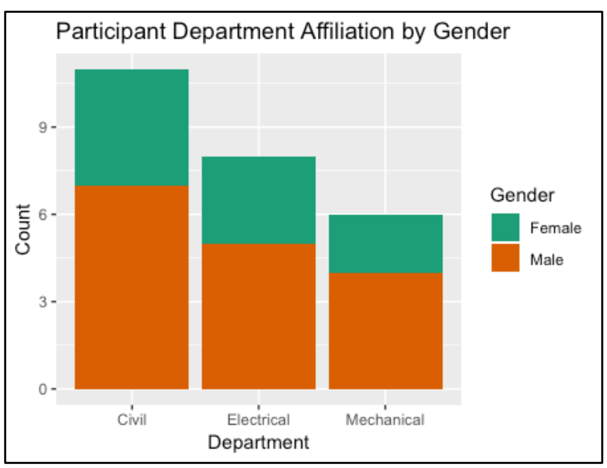

Figure 6. Distribution of faculty gender by discipline.

Table 4. Participant work experience counts.

Years	Count
0 years	4
0-1 years	3
1-3 years	6
3-5 years	3
5-10 years	1
> 10 years	8

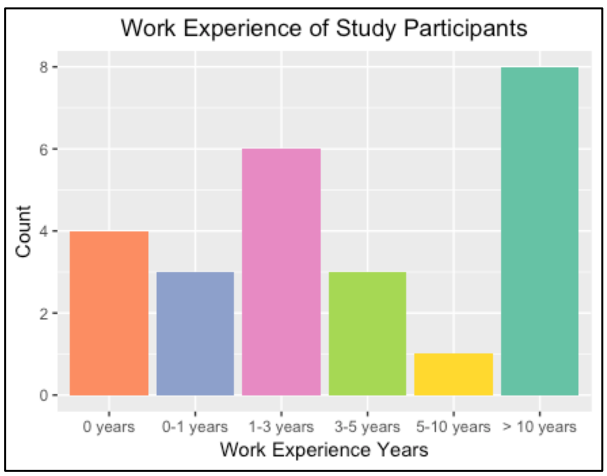

Figure 7. Distributions of participant work experience in industry by years.

Table 5. Participant position title counts.

Years	Count
Adjunct	2
Lecturer	1
Professor of Practice	3
Assistant Professor	7
Associate Professor	7
Full Professor	2
Professor Emeritus	3

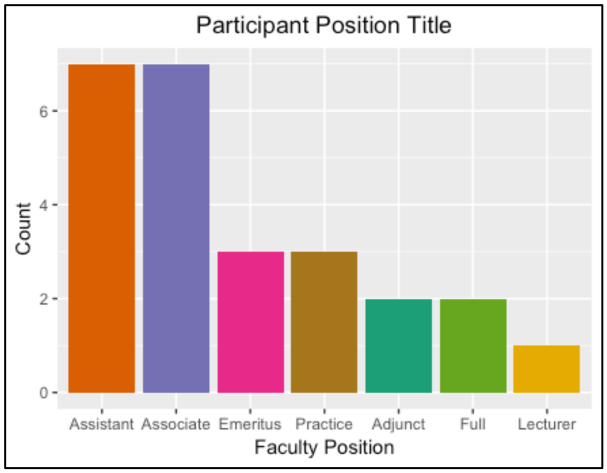

Figure 8. Counts of participants' faculty position total.

Table 6. Census divisions represented by count.

Region (states)	Count
1 (CT, ME, MA, NH, RI, VT)	0
2 (NJ, NY, PA)	2
3 (IN, IL, MI, OH, WI)	2
4 (IA, KS, MN, MO, NE, ND, SD)	3
5 (DE, DC, FL, GA, MD, NC, SC, VA, WV)	7
6 (AL, KY, MS, TN)	3
7 (AR, LA, OK, TX)	1
8 (AZ, CO, ID, NM, MT, UT, NV, WY	2
9 (AK, CA, HI, OR, WA)	5
10 (Islands)	0

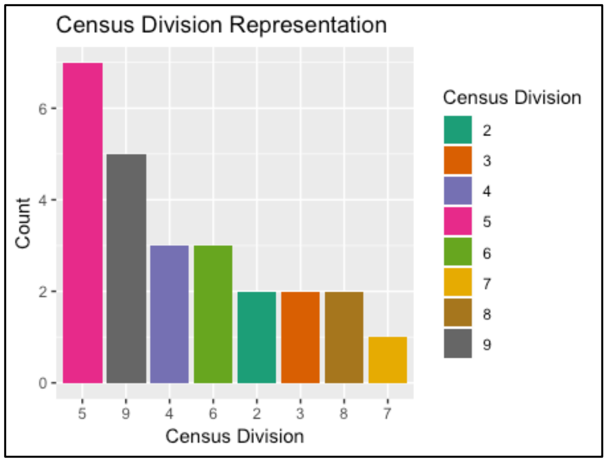

Figure 9. Counts of census divisions represented by participants.

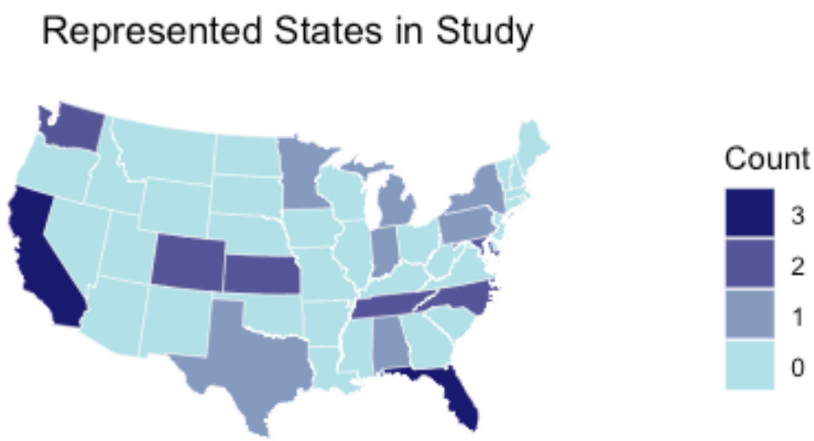

Figure 10. Frequency of states represented by participants in study.

Interview protocol development and description

To answer this research question, faculty member mental models were constructed from data collected using mental models interviews (Morgan et al., 2002) (also called cognitive interviews in systems dynamics research (Langan-Fox, Code, & Langfield-Smith, 2000)). The interviews in this study lasted between 50 minutes and 90 minutes. The interview protocol is in Appendix A.

The interview protocol was piloted through three iterations, beginning with graduate students and then moving to faculty members. Important areas of consideration in this process were clarity, brevity, and question appropriateness to avoid leading interview subjects. The question format was also designed to minimize effects of respondent acquiescence and social desirability. This was achieved by keeping the questions as neutral as possible. For example, rather than asking leading questions like "do you agree that engineering ethics should be taught?" the question "should engineering ethics be taught?" was asked instead. The participants were also reminded several times in the interviews that there were not any correct or incorrect answers and their honest answers were the main point of the study.

The interview questions were divided into two main sections. The first section contained questions about the faculty member's personal experiences in education, work, and teaching, while the second section contained questions about facets of the engineering ethics education system. The participants were informed about this division during the positioning phase of the interviews.

In a typical mental model method protocol, the questions in the structured portion of the interview protocol come from the expert model and they ask about general areas covered in an expert model. I did not use an expert model here because that is applicable when there is a "factual" (as in "facts of science") or generally accepted model of the system in question. On the other hand, this exploratory project focuses on a social system and is also predicated on exploring the space of potential models. Therefore, being a social system rather than a physical system, especially one with large variety and possibility, it seemed neither appropriate nor feasible to speak of having an expert model. In the data collection, no designation of "expert" was appended to any of the participants' mental models. Each model was collected simply as another landmark in the overall landscape that this study characterizes.

The interview protocol contained three phases. The first phase, positioning, involved explaining the purpose of the study, helping faculty members orient themselves to answer interview questions, and providing them an opportunity to ask questions before phase two. The second phase, personal experience, included questions about the participant's own education, teaching, and work experiences, including which parts of their courses, if any, relate to engineering ethics. The third phase, system model, included questions on the state(s), form(s), function(s), and purpose(s) of the engineering ethics education system. Questions focused on the inputs, processes, and outputs (i.e. educational outcomes) of engineering ethics education. Sample questions included: How do you think students learn about engineering ethics? How do you think students *should* learn about engineering ethics? How does engineering ethics education function within the engineering education system? In your view, what are some of the factors influencing how engineering ethics education? What are some of the goals of engineering ethics education? What do you think *should be* some of the outcomes of engineering ethics education? Participants were also asked to provide a working definition of engineering ethics, since that presumably affects how participants would answer questions about engineering ethics education.

All of the interviews were conducted and recorded for audio transcription purposes with the consent of participants, per Purdue University IRB protocol #1804020528. I then transcribed the interview audio for the analysis phase. I uploaded those transcripts for coding in NVivo 12 for the data analysis.

Data analysis

The data analysis involved multiple rounds of iterative coding. One of the main challenges when analyzing mental models interviews is the representation of that model. Historically, this has been done by identifying concepts and relationships and then graphically depicting the relationships between those concepts (Carley, 1997; Carley & Palmquist, 1992). This can also be done using influence diagrams, which depict causal relationships between a source and a target (Bostrom et al., 1992). I deemed influence diagrams to be too coarse for this project because they could lose some information about the nature (i.e., type and strength) of the relationships that populate participants' mental models. Specifically, there are more than causal relationships that populate the participants' mental models for certain classes of systems. Consequently, influence diagrams may be more appropriate for causal systems than for complex social systems that are higher up in Boulding's (1956) general systems theory hierarchy, e.g., complex social systems such as an engineering department. Therefore, I modified the method and did not code the transcripts for the purpose of constructing influence diagrams. Instead, I used a mental models coding approach that entailed coding the interviews according to different parts of the system being described in the transcripts – was a sentence describing the state, form, function, or purpose of the system? The following section elaborates on this approach.

Mental models coding

For the analysis in this study, I first coded the transcripts using a list of *a priori* codes, typical of a provisional coding scheme (Saldaña, 2013, p. 267). The provisional coding scheme provided an initial structure to the analysis and facilitated the next rounds of coding. The starting list of words for this provisional coding were also consistent with the mental models approach.

Specifically, following Rouse and Morris (1986), the codes were grouped into categories for "system state", "system form", "system function", and "system purpose", depending on which part of the participants' mental models of the engineering ethics education system a segment of the transcript corresponded to. Additional *a priori* child codes under the state/form/function/purpose coding scaffolding included elements from Lattuca and Stark's (2009) academic plan model that were specific to an academic plan within an education environment, such as: "instructional processes", "instructional resources", "content", and "purpose". These codes from the academic plan model fit within the overall coding scheme because the topics covered in the academic plan model and those in the interview both revolve around how to structure a curriculum to teach a particular subject. In other words, since I asked questions in the interviews about the different parts of an academic plan for engineering ethics, the codes informed by the academic plan model fit well within the overall coding scheme. The following sections outline the different classes of items that fall under each of the higher parent codes.

System form. The system form contains codes about the entities of the system. These loosely fit into categories of either concrete or abstract entities. Concrete entities include physical locations, instructional resources, and actors within the system. Abstract entities include intangible elements like time and responsibility or ideas such as the idea of ethics or the concept of consequentialism.

System function. The system function sections describe how the elements of the system interact. In relation to engineering ethics education, this specifically treated faculty members and students as the focal points around which the rest of the system was organized. Other actors contributing to the function included national organizations, industry, and other university entities. In short, the system function included the relationships between entities within the mental models. Those relationships were often in the form of actions, but this was not necessarily always the case. Such relevant actions related to the system function include instructional practices and learning mechanisms.

System purpose. Coding in this category corresponded to the reasons faculty members or students engage in particular tasks. For example, these could be reasons given by a participant to answer the question "why teach engineering ethics?" or "why have students complete a particular assignment?" They purposes often related to either faculty-centric purposes ("faculty members do this because…") or student-centric purposes ("students need to learn that…"). As a short hand, the system purpose is largely synonymous with the goals of the system or a subset of the system, depending on how one delineates system boundaries.

System state. The system state corresponds to the interrelationship between the different elements of the system (i.e., those entities identified as parts of the system form). Many of the codes in this category related to configurations of curricula, courses, departments, etc. There were also codes corresponding to internal and external dynamics, which arguably corresponds more closely with system function. Finally, this block of the codebook also comprised codes related to how a participant justified a configuration of the system state. For example, when describing how ethics was taught in a particular course, part of the state under this schema, participants would elaborate on the logic or justification for that arrangement. These justifications were part of their own codes within system state.

Finally, after coding for the high-level codes of state, form, function, and purpose, along with the specific elements of the mental models, I identified specific areas that could stand on their own as sections within a larger mental model of engineering ethics education. Within each of those areas, I identified patterns in the entities and relationships. These collections of patterns constitute the models in each of the areas that I present in the Results section.

Research quality

Multiple rounds of coding helped improve the credibility of the results. No inter-rater reliability since there was only one person coding the data. Instead, annotations and memos were taken to keep track of additions to the codebook and potential drift in the analysis over time. Aside from this change from multiple coders to one coder, the procedure was consistent with the mental models methodology (Bostrom et al., 1992).

With this approach to a mental models study, there are two notable assumptions that could affect the quality of the research. First, there is a methodological assumption that the interview produces a faithful representation of the participant's mental model of the system. In the interview design and development process I took care to minimize these types of errors in question selection and testing the protocol. Second, there is an analytical assumption that the researcher accurately codes the interview transcript to capture the salient features of each mental model. To address these issues, I posed follow-up questions for clarification and garnering supporting statements in the interviews as corroborating evidence. I also had the guidance of two committee members experienced with mental models research who reviewed and shaped my work throughout. Ultimately, working with the literature in these ways under the guidance of other experienced researchers helped identify places that I had to refine questions in the protocol.

Results

The primary results discussed here focus on models in ten areas of engineering ethics education. The ten are relatively self-contained but also communicate with other areas to varying degrees. Each area contains a collection of models that faculty members have of some aspect of engineering ethics education. They are pieces of individuals' mental models. Those ten areas are:

1. What engineering ethics is
2. The topics that comprise engineering ethics
3. Goals of teaching engineering ethics
4. Where students learn ethics
5. When students learn ethics
6. When ethics is taught (in curricula)
7. Who makes decisions about the engineering ethics curriculum
8. Who teaches engineering ethics
9. How faculty members teach engineering ethics
10. How students learn engineering ethics.

The models in each of the ten areas are presented in tables below.

Model areas and typologies

Model areas are specific sections of a mental model. They interface with other areas in the model and essentially correspond to subsystems of the larger system, viz., engineering ethics education. As shown in Figure 11, model areas are basically collections of related ideas that can inform or influence other areas. For shorthand, model areas are relatively self-contained clusters of constructs within the mental models that could merit their own, respective studies but which nonetheless do function together to form the whole mental model of the system. The areas loosely correspond to elements of the system associated with the who, what, where, when, why, and how of engineering ethics education. For example, how one defines the goals of ethics instruction (area two – the "why") can inform where students should learn engineering ethics (area three – the "how"), but it is also amenable to a more honed analysis by itself. In this study, the amenability to both individual and interactive analysis (i.e., studying the area itself and studying how the area affects other areas) is what defines an area of a mental model.

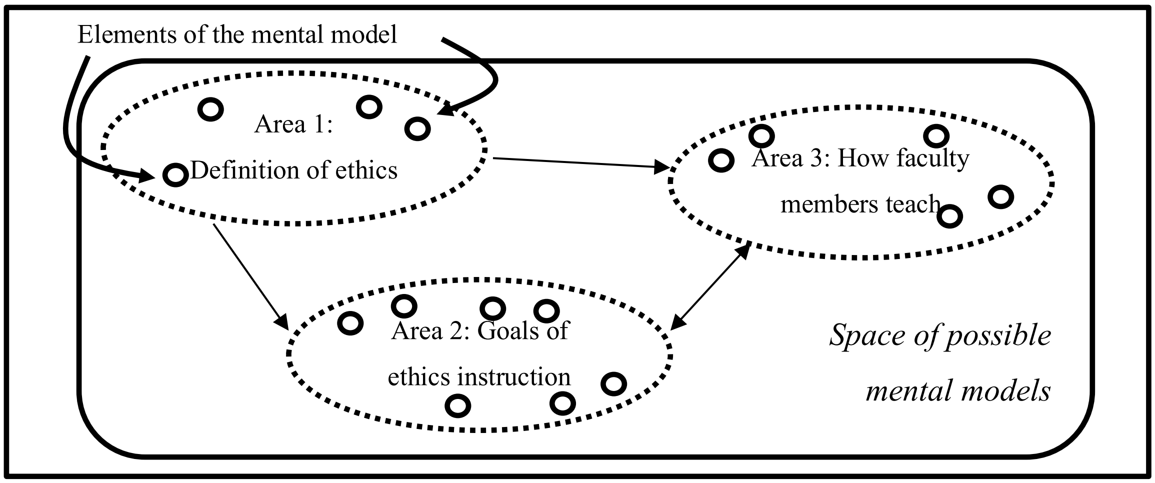

Figure 11. Relationships of mental model areas within the general mental model.

Under this formulation of model areas, the confluence of each area into a collective whole forms a person's mental model. Similarly, when characterizing the space of mental models, the aggregation of all the models in all of the areas from participants can form the entire space of possible mental models. The current study is designed to explore that entire space – all the models in each of the ten areas. As such, thoroughly characterizing the space of mental models requires accounting for models in each of the areas. This scheme has not been articulated in this way previously, but I suggest it can be helpful for organizing and analyzing different aspects of engineering ethics education. It is akin to establishing the landmarks in the space of models without saying anything about the size of those landmarks (which would be the analog of noting each model's prevalence in a population of faculty members).

There are two important notes about model types and how they combine. First, the following models in the different areas are not necessarily mutually exclusive. Instead, this typology describes a set of models. Sometimes those models can be mixed and matched. Other times those models are indeed incompatible or contradictory. Indeed, an avenue for further consideration would involve identifying which models are incompatible, and whether the same individual had those models, thereby possibly creating instances of cognitive dissonance.

Second, it is also important to note the existence of both descriptive models and normative models of engineering ethics education in each of these areas. A descriptive model describes the system as it *is*; a normative model describes it as it *should be*. For example, a faculty member's mental model of how faculty members teach engineering ethics might be connected to professionalism – reviewing codes of ethics, fiduciary responsibility, and topics typically grouped under microethics. That same faculty member's normative model, on the other hand, could be a more expansive model that involves case study discussions, role-playing, and active debate. In this case, there would be a gap between their descriptive model of ethics teaching and their normative model of that area. In the interviews, I collected data on both of these. In general, some participants demonstrated minimal divergence between their descriptive and normative models while others clearly maintained a separation between the system in its current form vis-à-vis the system in its potential form.

The following paragraphs briefly discuss the models in each of the ten areas. I have created a typology for each of the areas in order to characterize the space of mental models. The goal of elucidating the model types in each area is to provide a lens for administrators, researchers, and educators working on issues that involve engineering ethics to be able to quickly identify which models preside within the observers' contexts. Each of the ten areas has a brief definition and introduction describing the meaning of that area, a table listing the models for that area, and then a short overview of those models in the table.

Area 1: What is engineering ethics

The definition of engineering ethics and engineering ethics education is possibly the nucleus, and therefore sine qua non of a mental model of engineering ethics education. This area may be considered the area from which all the other areas emanate. The area includes but is not limited to specific issues related to engineering ethics (e.g., due diligence, honesty, whistleblowing), workplace issues (e.g., teamwork, sexual harassment), philosophical ideas (e.g., utilitarianism, duty ethics), and broader ethical issues related to what one may call macroethics (e.g., sustainability). The "what" is an important area to account for because there is no Platonic ideal of engineering ethics. Meaning is use (Wittgenstein & Anscombe, 2000, p. PI 43), and one's use of the term engineering ethics, controvertible though it may be, is going to manifest in the classroom and form the basis for one’s own mental models and subsequent actions. Table 7 shows the models for area one.

Table 7. Models of definitions of engineering ethics.

Model name	Model description	Representative quote
Professional responsibilities	Engineering ethics is the standard of conduct agreed upon by the professional engineering community	*“Engineering ethics, I think, is the way engineers, probably working in a professional context, interface with others in a professional way.” [Int 20]*
Social responsibilities (Spider man model)	Engineering ethics is about engineers learning their social responsibilities (with great power comes great responsibility)	*“I guess engineering ethics is about looking beyond what you're required to do or the technical content of what's required and evaluating more along the lines of a social responsibility.” [Int 17]* *“Again, my view of engineering is to make people’s lives better. Improve the quality of life or the quantity of life. Engineering without an impact on people is worthless and if you're impacting people then you have ethical responsibility or social responsibility.” [Int 16]*
Black box	Unawareness of any specific elements of engineering ethics	*“I am a civil engineering professor and I don't really even know what the engineering ethics are. I couldn't name you one canon other than maybe or the codes, I don't know if I’m calling it the right thing, I even forgot that.” [Int 19]*
Simon says	Engineering ethics is about following rules, whatever they may be and whoever creates them	*“It’s just them understanding the rules of the road so to speak. It’s like trying to get a driver's license, right? You have to teach them what all the signs mean and what happens if you don't obey them.” [Int 22]*
Community standards	Engineering ethics is whatever the professional community decides is should be	*“I personally, define ethics as a set of rules and regulations which the community has to follow once they all have consensus about it.” [Int 15]*

Table 7 continued

Academic issues	Engineering ethics as responsible conduct of research, academic integrity, plagiarism, etc.	*"So I included a little bit about it there and that included academic integrity which I'm sure you're well familiar with because that's ethics." [Int 01]*
Legality	Engineering ethics as intellectual property, copyright, etc.	*"...more legalistic type things, yes, may fall into the engineering ethics. But for an undergraduate I keep going back to that conflict of interest but that is a really important one that sticks out in my mind at least, especially younger engineers need to be aware of." [Int 19]* *"So basically following the established laws of the land is what makes things ethical." [Int 15]*
Research ethics	Engineering ethics includes responsible conduct of research	*"They're emphasizing research and they can talk about research ethics, but that's a different kind of ethics than when you're actually working in industry and you're working with clients." [Int 10]* *"I think usually at its most basic form it's the multiple choice RCR training, which is just gut wrenching." [Int 18]*
Micro ethics	Engineering ethics is about day-to-day scenarios that engineers face	*"Yes of course micro ethical issues, behaving ethically, not taking bribes, the things that play into the day-to-day" [Int 03]* *"Engineering ethics is more about what happens on the day to day, I got a telephone or somebody walked into my office, yea, that part they need to know or they're not as valuable as they could be to their employers." [Int 24]*
Macro ethics	Engineering ethics is about large issues that engineering as a profession faces	*"So what I've done mostly there is try to incorporate... pretty superficial but try to incorporate some kind of macro ethical considerations." [Int 14]*

Table 7 continued

Codes of ethics	Codes of ethics indicate the meaning of engineering ethics	*"what it means is defined by a large social group. And so you find many things in there. I think broadly agreed upon things would be the professional canons and the basics of those things that all engineers really ought to agree on." [Int 25]*

The definitions of ethics ranged from microethics issues concerning everyday behavior in the workplace to macroethical issues about the role of engineering in society. Some faculty members had a model of engineering ethics that depended on professional communities of practice and consensus in those communities. Other models focused on engineering ethics as something inherent in the *practice* of engineering (rather than inhering in the *status* of engineering being a profession or its practitioners). This difference highlights a common question throughout many of the areas – how much does engineering ethics and engineering ethics education depend upon engineering's status as a profession? Although that sounds like a philosophical question, it has numerous practical implications, as the results suggest, because it affects the models in these different areas. That question also has implications for whose voice might count when deciding what comprises engineering ethics, an issue explored elsewhere in a broader conversation about articulating non-canonical canons of engineering ethics (Riley, Slaton, & Herkert, 2015).

Area 2: Topics of engineering ethics education

The contents of engineering ethics *education* are a separate area beyond the contents of engineering ethics. They comprise the topics to cover in engineering ethics education and therefore bear close resemblance to the contents of engineering ethics. Table 8 shows the models for area two.

Table 8. Models of ethics content.

Model name	Model description	Representative quote
Professional ethics	Engineering ethics education is synonymous with professional ethics	*"[Students learn] professional practice ethics of knowing how to follow the rules, being obligated to understand what those rules are and how they constrain your process" [Int 22]*

Table 8 continued

Social responsibilities	Ethics content contains learning the social responsibilities of a professional engineer	*"Again, my view of engineering is to make people's lives better. Improve the quality of life or the quantity of life. Engineering without an impact on people is worthless and if you're impacting people then then you have ethical responsibility or social responsibility." [Int 16]* *"I guess engineering ethics is about looking beyond what you're required to do or the technical content of what's required and evaluating more along the lines of a social responsibility." [Int 17]*
Social issues	Engineering ethics as related to social issues, e.g., sexual harassment, discrimination, social justice	*"Including sexual harassment. Some of the girls and some of the women in class had some experiences that they shared." [Int 01]* *"I think discrimination issues…I think that would be good to teach." [Int 04]* *"There's another faculty member who has incorporated some social justice work into her class."[Int 14]*
Academic ethics	Engineering ethics as responsible conduct of research, academic integrity, plagiarism, etc.	*"So I included a little bit about it there and that included academic integrity which I'm sure you're well familiar with because that's ethics." [Int 01]*
Legal ethics	Engineering ethics as intellectual property, copyright, etc.	*"…more legalistic type things, yes, may fall into the engineering ethics. But for an undergraduate I keep going back to that conflict of interest but that is a really important one that sticks out in my mind at least, especially younger engineers need to be aware of." [Int 19]*
Research ethics	Engineering ethics includes responsible conduct of research	*"they're emphasizing research and they can talk about research ethics, but that's a different kind of ethics than when you're actually working in industry and you're working with clients." [Int 10]* *"I think usually at its most basic form it's the multiple choice RCR training, which is just gut wrenching." [Int 18]*

Table 8 continued

Micro ethics	Engineering ethics is about day-to-day scenarios that engineers face	*"Over time they could hear multiple points of view and talk about the micro ethics and the macro ethics and sort of technical elements and also research, you know, stuff that might really relate more to like the academic engineering side of things." [Int 18]*
Macro ethics	Engineering ethics is about large issues that engineering as a profession faces	*"So what I've done mostly there is try to incorporate... pretty superficial but try to incorporate some kind of macro ethical considerations." [Int 14]*
Codes of ethics	Codes of ethics as a part of teaching engineering ethics	*"It's partly studying and learning the codes of ethics that are put out by different professional bodies, but also seeing how those codes and the behaviors of practicing Engineers have led to successes" [Int 02]*
	Unobserved models	
Black box	Unawareness of any specific of engineering ethics education	

The models of topics in engineering ethics education varied from professional ethics to social ethics, academic ethics, and research ethics. The diversity of topics and definitions covered in the models in areas one and two together suggests that there still exists a large amount of heterogeneity in what engineering ethics means to faculty members. Depending on one's disposition, this might create an opportunity to work toward arriving at some consensus or continue pushing the boundaries of understanding. In combination with area one, at a minimum it suggests continued caution and clarification when using the term "engineering ethics" because it can signify different things to different people.

Area 3: Goals of ethics instruction

The goals of ethics instruction tended to reside primarily in the system purpose dimensions of participants' mental models. This area was most commonly discussed in response to questions about why faculty members should/do teach ethics and why students should/do learn engineering ethics. Goals ranged from focusing on the engineering profession (i.e., introducing students to professional responsibilities) to focusing on a humanistic justification (i.e., developing well-rounded citizens capable of contributing to society). Collectively these answers correspond to individual faculty members' goals, departmental goals for the curriculum, and even more systemic goals that apply to engineering education writ large. The goals inform most other areas of the mental models. I explore this idea in the discussion section. Table 9 shows the models for area three.

Table 9. Models of goals of ethics instruction.

Model name	Model description	Representative quote
Student development	Engineering ethics education is about helping students to develop as people and not just as future professionals	*"This is exploratory. There's more growth and development there…It's Formative for their whole person not just the topic area." [Int 25]* *"I think part of our whole mission was to prepare them to go into industry as good people, confident people, good communicators, well-rounded and hard-working and all that stuff." [Int 01]*
Practice with safety net	The goal is to expose students to decision-making in a low-risk environment and failing	*"I think getting them a lot of practice in situations that are low stakes is a lot better in the long run than expecting them to make these decisions in smart ways when they are faced with them for the first time in the workplace." [Int 20]* *"University is where you learn it for free without cost, meaning without costing you your job, without consequences." [Int 15]*
Practice failing	Students learn by failing, so the goal of ethics instruction is for students to practice failing at making ethical decisions and then learning from their mistakes	*"I think almost every student learns through failure." [Int 17]*
Improved decision-making	Goal of ethics education is for students to improve their decision-making abilities	*"For the engineering students to be able to make correct judgments and reasoning when they practice engineering, which includes design stage and then construction stage" [Int 05]*

Table 9 continued

Identity development	Engineering ethics education is about developing identity as an engineer and integrating that into self-identity	*"I think the question of engineering ethics has to be a question of identity development and values development, that being an engineer is who you are as a person for most people that are engineers. It's not something that you can separate out, and so engineering ethics has to be something that grows into who you are, which is an engineer with ethics to be integrated and meaningful." [Int 25]*
Recognition	Goal of ethics instruction is for students to recognize ethical dilemmas in practice	*"I want students to recognize the situations where it can occur so that when they are faced with an ethical decision that they can recognize it sooner than if they hadn't thought about it" [Int 04]*
Awareness + Recognition + Judgment	Goal is for students to be aware of the fact that these ethical dilemmas may arise when they work as engineers	*"The point of ethics education is to raise students' awareness of the fact that these other issues are going to be there and you really need to recognize when they are there and be able to be conscious of how you deal with them I guess is the best way to think about it. So it is really an awareness." [Int 06]*
Professional preparation	Since engineering ethics is connected with professional engineering (in some mental models), engineering ethics education is about preparing students for a dimension of working as a professional engineer	*"It is the one professional degree that you can get at the undergraduate level. Like medicine and law they are post-secondary or postgraduate. I don't want the students leaving thinking this is just a ticket to a well-paying job. There are serious responsibilities that you have." [Int 02]* *"I think engineering ethics education has to do with how we prepare undergraduate and graduate students to behave in more professional ethical moral ways." [Int 20]*

Table 9 continued

Understanding professional responsibilities	Goal is for students to learn responsibilities as engineers	*"one is them understanding the sources and reasons for the rule books that guide them as engineers, just from a purely practical you'll get fired or arrested if you do these things as an engineer kind of a thing"* [Int 22]
P.E. license preparation	Students will need to know ethics for their F.E. and P.E. license examination	*"We are making everybody take the test, the FE senior year…And so sort of with the basics, we cover that. And I feel like it's straightforward enough that everybody should understand it. There's not a whole lot of debate about those things." [Int 25]* *"To do certain tasks have, certain jobs in the industry, you have to have different types of licenses. For example a Professional Engineer's license, and if you have a Professional Engineers license, of course, there are all sorts of ethical obligations that that come along with that." [Int 22]*
Work preparation	Students need to learn ethical decision-making because that's what companies expect	*"it's important for the students to be exposed to that, um, and to where they're better prepared when they go out into the workforce" [Int 07]*
Prepare to be a better citizen	Teaching students to be better citizens once they graduate	*"There's an understanding that you're learning a particular profession, but you're also being prepared to be a citizen and a contributing member of society, so we're trying to create well-rounded people." [Int 01]*
Check the (ABET) box	Teach ethics in order to check the box for ABET accreditation	*"It's required for civil and environmental engineering students, and I believe they're doing that for the ABET ethics requirement. I don't know that ABET really cares that you have a separate class, but you better document that you teach ethics." [Int 08]* *"ABET requires it. Engineering people tend to be very utilitarian. They'll say okay, we'll check this box off. We'll optimize this. We do have to do this. We have this requirement." [Int 16]*

Table 9 continued

Unobserved models	
Black box	Unawareness of any specific of engineering ethics education

Models of the goals of teaching engineering ethics focused on: relationships within the profession and between engineers; relationships with business and employers; relationships with other people and society; and relationships with the environment. Some models were more circumscribed than others, setting a simple bar to clear when teaching ethics. Another way to look at these models: how much do they emphasize personal development versus joining a community? For some models, the goals focus on the individual student – their ability to make decisions, their identity, their sensitivity to ethical dilemmas. In other models, the goals focus more on joining the professional community. The models with goals for personal knowledge, awareness, judgment, and ability to act are consonant with prior literature on the purpose(s) of teaching engineering ethics (shown below in Table 10). The models with goals for meeting the standards of a community are less documented and thus present an interesting question: are there some disciplines within engineering that might emphasize this collective attitude more than a lone-wolf mentality of personal development?

For comparison, Table 10 shows some of the common goals of engineering ethics education referenced in the literature. Two models that did not appear frequently in the literature but did appear in the study were "prepare for work" and "prepare for P.E. license". This may highlight a disconnect between some faculty members' focus on professional development in many areas of their mental models when compared to other faculty members whose models have less of a prominent role for the profession to occupy.

Table 10. Goals of ethics education from literature.

Goal	Citation
Disaster avoidance	(Harris, Davis, Pritchard, & Rabins, 1996)
Satisfy ABET outcome 3.f (ability to understand professional and ethical responsibility)	(ABET, 2016)
Satisfy ABET outcome 3.h (the broad education necessary to understand the impact of engineering solutions in a global and societal context.)	(ABET, 2016)
Facilitate student moral development	(Cruz & Frey, 2003; Patricia Hogue Werhane, 1999)

Table 10 continued

Question decisions, practices, and processes	(Hollander, Arenberg, & National Academy of Engineering, 2009)
Stimulate student moral imagination	(Callahan, 1980)
Minimize Academic dishonesty	(Holsapple et al., 2012)
Research integrity	(Kalichman, 2013)
Emotional engagement	(Newberry, 2004)
Intellectual engagement	(Newberry, 2004)
Particular knowledge	(Newberry, 2004)
Students have ethical sensitivity	(Davis, 1999)
Students have ethical knowledge	(Davis, 1999)
Students reach ethical judgments	(Davis, 1999)
Students have ethical will-power	(Davis, 1999)
Capacity development	(Callahan, 1980)
Ability to understand ethical issues beyond individual context	(Bucciarelli, 2008)
Better designs (by improving ability to handle uncertainty)	(Whitbeck, 2011)

Area 4: Where do students learn engineering ethics

Another area of faculty members' mental models of engineering ethics education is the location of teaching and learning. The list of learning locations includes classrooms, internships, full-time work, and extracurricular activities. This area focuses on physical locations. Area six, on the other hand, focuses on the question "where in the curriculum" and is framed more in terms of time (i.e., when) than location (i.e., where). Table 11 shows the models for area four.

Table 11. Models of physical environments for learning engineering ethics.

Model name	Model description	Representative quote
Classroom	Students learn ethics in classroom settings	*"I think students being exposed to that in a formal classroom setting at least exposes them to the idea that the rules exist and we expect them to follow them." [Int 22]*
Workplace	Ethics education occurs in workplace settings during internships and/or full-time employment	*"I think most of them learn it on the job." [Int 10]*

Table 11 continued

Everywhere	Engineering ethics education occurs everywhere, all the time	*"There have been some interesting papers that somebody has passed on to me that they call it microethics education or something where it is distributed everywhere." [Int 06]*
At home	Learning ethics at home, and that carries over into engineering ethics	*"I think that maybe some of the norms of ethics that existed before were based in core values that maybe you learn at home, but I think that there are new things that are happening today that are beyond that. So there is need for education into ethics, like ethical issues that arise as a result of those advancements." [Int 21]*
Extracurricular activities	Students learn engineering ethics outside the classroom participating in extracurricular activities	*"I think it happens a lot of the time outside the classroom in their co-curricular experiences." [Int 20]*
Pass the buck	Faculty think students learn on job, industry thinks students learn it in school	*"I imagine that faculty believes that students will learn it on the job and the profession believes that students will learn it in school and everyone is willing to look the other way and no one will learn it." [Int 03]*
	Unobserved Models	
Black box	Students learn it at some point, but not sure where	

Models of where students learn were consistent with prior research suggesting that students learn ethics in their place of employment, participating in extracurricular activities (Finelli et al., 2012), and in their engineering classrooms. The models in this area emphasize the possible outlets for people interested in studying or improving engineering ethics education – there are numerous physical locations to accomplish this.

It may be helpful to consider the implications of models in this area with models in area 8 (who teaches) and area 10 (how students learn). For example, who is teaching engineering ethics in the extracurricular activities model? Could there be potential gaps or inconsistencies that arise from combining certain models? If one combines the learning through failure (for how) and extracurricular activities models (for where), are there ways to improve student learning through increased feedback loops? Using the models in this way might provide a helpful framework for identifying specific places to improve engineering ethics education.

Area 5: When do students learn engineering ethics

The preceding area was on the physical location of student learning. Location, however, can also assume a less physical meaning to signify location in time. Therefore, area five of faculty mental models concerns when students learn engineering ethics. It includes points in time before, during, and after a student's formal university education. This area is different from area six because that area focuses more specifically on curriculum structure and when ethics is taught whereas area five focuses more on when students learn. These are not necessarily the same thing. Table 12 shows the models for area five.

Table 12. Models of when students learn engineering ethics.

Model name	Model description	Representative quote
Before university	Students learn engineering ethics when they are growing up	*"I think a lot is that their like ethical frameworks are developed before they come to us. Something to think about, like personal ethics. And I think that that often does play a role in their views and perspectives on engineering ethics." [Int 14]*
On the job	Students learn engineering ethics on the job	*"I think the vast majority I'd say learn it on the job and hopefully they learn it from good people that they're, that they're working with." [Int 07]*
From day one	Students learn engineering ethics from the beginning of their time at university	*"I think starting in the first year of engineering study is pretty important. I wouldn't want to wait. In the first year of engineering studies you're introducing what engineering is, and so if you don't say it early you're going to have said all these things we talked about first are more important." [Int 25]*

Table 12 continued

Toward the end (homestretch?)	Students learn engineering ethics in their third and fourth years once they have seen multiple engineering courses	*"There may be litigations or something that happens so ethical issues are brought up. That would be the where in the world outside of school. But inside of school like we were saying at junior or senior level." [Int 21]* *"It makes sense towards the end, but I know these people go out on internships, too. It's just the end they're more mature and they've seen a lot of other courses. A senior, and it's usually maybe it's like fresh in their mind and they go out in the industry. But it's kind of like a nice culmination of all this technical knowledge that they acquired over the years at school. Then we teach them how to perform well in practice." [Int 23]*
Co-op or internship	Students learning during co-op or internship opportunity	*"when you do a summer job as a student, you do learn some ethical situations and you learn a little bit about, uh, what, what do you call it? The office activities." [Int 12]*
Continuing education course	Students (now practicing engineers) learn ethics during continuing education course for P.E. license	*"I'm a licensed professional engineer and part of that is you have to have hours of ethics. That's a requirement." [Int 09]*
	Unobserved Models	
Black box	Not sure when an engineer learns engineering ethics in their life	

The models in this area covered the range of possibility and were a reminder that some of these models (regardless of the area) are not mutually exclusive. There were models for most stages of a student's life. They started from before university as a student is growing up and continued into the workplace and even formal continuing education courses. The more protracted mental models that envision students learning at multiple stages agree with other theories of general moral development (e.g., Kohlberg) or reflective judgment (e.g., King and Kitchener). In those frameworks development begins at an early age and extends beyond a traditional university age.

When considering how to structure a department's curriculum, it may be necessary to consider whether some faculty members have the "from day one" model while others have the "toward the end" mental model. Hypothetically, this could create a point of tension because the latter model suggests students should not learn engineering ethics until they have taken some engineering courses. Convincing a faculty member with the "toward the end" model to teach ethics in their introductory class could therefore require extra convincing, including information about the value of more frequent ethics education.

The reader should note that the distinction between the "when" and "where" areas for student learning may occasionally be dubious. Sometimes there are clear distinctions: physically learning at a workplace (a model of where students learn) versus learning during adolescence (a model of when students learn). Other times the distinction is blurry at best: learning at a workplace (model of where) versus learning while working (model of when).

Area 6: Where in the curriculum ethics is taught

Accompanying mental models of when students learn engineering ethics is an area of when engineering ethics is taught. This area corresponds to the structure of engineering curricula. The models in this area account for the courses in engineering programs and their arrangement. The models in this area also more holistically describe engineering programs as more than the sum of their parts. For example, the book ends model describes a curricular structure in which engineering ethics is taught at the beginning of an undergraduate engineering program in an introductory course and the end in a senior capstone course. Table 13 shows the models for area six.

Table 13. Models of when engineering ethics is taught.

Model name	Model description	Representative quote
Book ends	Engineering ethics is taught in the first and last courses in the department's undergraduate program, forming book ends.	*"You have this mandatory course in senior year. In freshman year, there's an introduction to engineering course and it's also required that that course includes ethics" [Int 02]*
Ethics across the curriculum	Teaching ethics consistently throughout the program	*"I think it should be embedded in all the courses we teach." [Int 23]*

Table 13 continued

		Everything has an ethical thing." [Int 11]
Lonely island	Engineering ethics instruction is isolated in the curriculum from the rest of the content that students learn. The instructor is often also isolated from the rest of the faculty	Being the ethics person: *"They asked me to teach it. I've never said no to anything they asked me to teach. I've just evolved into this ethics person now" [Int 08]* Isolated content: *"I just know my class and as I said for the last five years for better or worse I am the only one teaching it." [Int 08]* Faculty isolation: *"I'm not there [in the offices], so I can't ask them [the other faculty]" [Int 08]* *"I mean I'm kind of my own little island" [Int 07]*
Vaccination	A one-time exposure inoculates the students against unethical behavior.	*"It is interesting that the perspective is we will just give them one class in engineering ethics and that is going to fix it" [Int 06]*
Ad hoc	Engineering ethics appears sporadically in disparate courses at the whim of the instructors; sounds similar to ethics across the curriculum, but without the intentional coordination	*"I think the reality is that most places and just falls to the individual faculty member and their motivations and interests and that on the positive sides has created some really amazing examples of ethics education in engineering but on the negative side it means it is not a movement. There is no systematic teaching except for the bare minimum for inclusion of ethics." [Int 03]*
Crowding out	A minimal quantity of engineering ethics in the curriculum structure is the result of being crowded out by other coursework.	*"Part of the reason that they don't is again, is the crowding out." [Int 12]*

Table 13 continued

Implicit instruction	Engineering ethics is never explicitly discussed	*"I would say though that there was definitely implicit, just maybe not explicit required instruction, but you know, knew what was right and wrong about plagiarism, things like that and those responsibilities. But I have to say, I don't think it was explicit, like, here's an ethics class." [Int 09]* *"I don't explicitly necessarily use the word ethics but it's meant to reinforce the enormity of the responsibility that is on their shoulders as individuals when they become a practicing engineer, whether it's seeing a teammate do something that you don't approve of or don't agree with and whether you go along just to get along or whether you speak up as your sense of obligation to make sure that things are done properly." [Int 22]*
Explicit instruction	Engineering ethics discussed by name in a course or other formal setting	*"And then our students are required to take a two-credit professionalism and ethics course prior to graduation where one part of it covers ethics." [Int 20]*

This area of mental models corresponding to curriculum structure displayed a large gap between normative models and descriptive models. The models in this area are similar to some of those that Katz and Knight (2017) described, particularly the "book ends" and "lonely island" models. For anyone interested in incremental improvement toward implementing the "ethics across the curriculum" model, it can be important to consider one's starting point. For example, if the prevalent mental model is the "book ends" model then at least there is some structure and multiple places in the curriculum where students learn engineering ethics. On the other hand, if the starting point is a "vaccination" model then there will be more work to be done by the reformer(s) because this requires building the case for why one-time exposure is insufficient when it comes to learning engineering ethics.

Area 7: Who makes curricular and pedagogical decisions

The people and processes for making decisions that affect the broader engineering education system is another area of faculty mental models. This constitutes an entire discrete area of a mental model because it includes a collective class of actors and relationships that affect the state of the engineering ethics education system. The area captures power dynamics within departments and how those may affect formal engineering ethics education. Table 14 shows the models for area seven.

Table 14. Models of decision-making.

Model name	Model description	Representative quote
Democratic	Decisions made by voting in groups	*"And then our faculty as a whole talk about how we are going to teach these things and choose different courses where we might teach it" [Int 04]*
Autocratic	Decisions made by a single individual on behalf of a group	*"We've never, never had a conversation about whether that is like what we should or shouldn't be doing. The course, like historically was run, like kind of coordinated by one kind of senior teaching faculty member who everybody like really respected and kind of deferred to. So I think we're still kind of seeing the impact of him. So no... that as far as I know, everyone's kind of adopted how he presented it to his section and everybody else has kind of just followed suit." [Int 14]*
Committee work	Decisions made by a group (i.e., a committee) that affect other faculty members	"*We review whether or not they're meeting the requirements. So we as a committee evaluate these assessments or even how things are introduced" [Int 09]* *"The contents of individual classes is really in the hands of the faculty who teach it, unless there is a course that is being taught by multiple professors. Then there is the committee." [Int 15]* *"Depending on current ideas the university may create or the college of engineering may create an ad-hoc committee to think about ethics instruction." [Int 20]*

Table 14 continued

Partnership	Instructional decisions made in conjunction with co-instructor for a team-taught course	*"most of the time the two didn't coordinate very well, but with one guy we actually coordinated two of our assignments together" [Int 01]* *"Well it was pretty much all just logistical in time because we had about seven engineering instructors and two to three philosophy instructors and you never knew who you got matched up with. So it was just too hard to coordinate all of that." [Int 01]*
ABET committee	ABET committee makes decisions about curriculum	*"So when we revisit our course materials and notice that based on the syllabus that we have back from a faculty member the course that used to have ethics no longer does have ethics then we make sure we go back to the instructor to get that placed back in. So we work with the faculty in our department to think about the way that ethics is integrated into the curriculum. So at the department level we have a curriculum committee that makes decisions and works with faculty to implement those decisions related to ethics instruction." [Int 20]*
Delegation	Different individuals delegated to make different kinds of decisions	*"I think the main factor for our department would be this is kind of top-down tasking of a certain course to demonstrate that we are teaching engineering ethics in sort of a backwards way. It's like, by the way, you are teaching engineering ethics in this class." [Int 13]*
Fiefdom	Everyone makes their own decisions for their own course	*"What I've experienced here and working through ABET there isn't that direct prescription that there has to be an ethics course…It is left entirely up to the professors." [Int 02]* *"I had absolute freedom to do whatever I wanted. No one else knew or cared. Well it's not that they didn't care it's just that they didn't know or have any input on what was in that course." [Int 03]*

Table 14 continued

Principal-agent	Principals outside the department make decisions that faculty members must carry out	*"We talked with the people on that [industrial advisory] council to guide us in terms of what was important for their companies and what they thought for what content we should have in these threats and then to also help us with opinions on how to deliver that content." [Int 16]*
Student input	Students given a voice in the decision-making process	*"Somebody brought that up and said well let's talk to the students and see what they think about the class and they said uniformly that they thought the class was terrible and that they didn't learn anything and we already had a writing-intensive class elsewhere in the curriculum, in particular lab courses and things, so the point was brought up and we had a discussion with the curriculum committee and they said we can remove that particular requirements and we went through the process of figuring out how do we just remove that." [Int 06]*
Prescription	Some external organization prescribes some dimensions of ethics education	On ABET-informed vs Canadian engineering education*: "what I've experienced here and working through ABET there isn't that direct prescription that there has to be an ethics course, so in the program here nowhere are students formally exposed to engineering ethics. It is left entirely up to the professor…When I was teaching [in Canada] I got a better sense of what was prescribed and what was actually voluntary. The prescribed element was actually quite heavy. You have this mandatory course in senior year. In freshman year, there's an introduction to engineering course and it's also required that that course includes ethics"[Int 02]*
	Unobserved models	
Black box	Unawareness of any specific of engineering ethics education	

Lessons from models in this area extend beyond engineering ethics education. Specifically, there are two simple but practical lessons for anyone interested in curricular reform: (1) different departments have different mechanisms for making curriculum decisions and (2) there may be competing models for decision-making in the same department, in which case the source of the ultimate decision is ambiguous. For the first lesson on diverse mechanisms for deciding in groups, this means that strategies to improve engineering ethics education in some settings – i.e., appealing to curriculum committees – may be less effective than in other settings where the committee is ineffectual or a "prescription" model prevails. Indeed, with the "prescription" model, an entirely separate focal point for efforts is required. For the second lesson on competing models, this raises an open question for future research to investigate how faculty members resolve conflicting messages about curricular or pedagogical priorities. With centralized planning, there could be an element of shared understanding among faculty and consistency in the curriculum that students see. On the other hand, decentralized decision-making could create "pockets of innovation", as one participant described it.

On a separate note, there were comparatively few mentions of models that incorporate students in the process. It is unclear whether this was an artifact of descriptive models or both descriptive and normative models. In other words, it opens the question: what role do faculty members see for students in shaping how they learn and what they learn? Several motivation theories would suggest that empowering students in designing their own learning experiences is an effective way to improve their academic motivation (Jones, 2009). Could an increased awareness among faculty members of this motivation research help change models of curricular and pedagogical decision-making?

Area 8: Who teaches engineering ethics

Area eight corresponds to who teaches engineering ethics inside and outside of university settings. It includes both normative and descriptive models of ethics teachers. This area is an extension of the area on decision makers because some of the deciders are also subsequently teachers, but the two areas also distinct because this focuses more on the individuals in direct contact with learners. Table 15 shows the models for area eight.

Table 15. Models of engineering ethics teachers.

Model name	Model description	Representative quote
Seasoned veteran	Engineers with extensive work experience should be the ones teaching engineering ethics	*"You need to get another guy* [sic] *who's ready to retire to come in. I almost think this has to be done by an experienced industry professional." [Int 24]*
Normative/ descriptive gap	There is a discrepancy between what the faculty member says they think should happen and their self-reported behavior	In response to question of who should be responsible for teaching engineering ethics? *"I think everyone should be in the department" [Int 12] +* In response to question (are there elements in the courses that you teach or that you taught that incorporated engineering ethics in some way?): *"No, no, no. I'm supposed to only talk about circuits and any kind of illustration that deals with circuits or feedback control or the other." [Int 12]*
Only the trained	Only taught by people trained to teach engineering ethics	*"We felt like a person who could teach ethics in our progress will be a person a person who is trained into it." [Int 21]*
It takes a village	Everyone teaches (or should teach) ethics in their courses	*"We have the power and the responsibility to teach our students how to be good citizens, good ethical citizens, and that should be on every professor's shoulders." [Int 11]*
Adjunct/utility player	The adjunct faculty member is the person who teaches engineering ethics	*"I'm an adjunct. I was formerly full-time. I come out of the bullpen…I also have a 100% online ethics course that's offered all three terms of the year." [Int 08]*
***Laissez-faire* / Academic freedom**	Each faculty member is free to innovate and teach what they want (including deciding whether to teach any ethics at all)	*"I think the reality is that most places and just falls to the individual faculty member and their motivations and interests and that on the positive sides has created some really amazing examples of ethics education in engineering but on the negative side it means it is not a movement. There is no systematic teaching except for the bare minimum for inclusion of ethics, so the pros of that is that a creates some real innovation the cons is that it just lives in pockets of innovation, pockets of exemplars" [Int 03]*

Table 15 continued

Outsourcing	Someone outside the department teaches ethics because the department decided to outsource the class	*"Everyone decided that it was way easier just to pay for that person and part for the instructor in the Philosophy Department to teach it than for us to worry about teaching ethics in our classes." [Int 06]* *"They outsource it to centers for teaching and learning, which are out of touch. It's just, you know, I think it's the exact same thing operating in the ethics domain." [Int 18]*
Philosophy with a philosopher	Engineering ethics taught by a philosopher	*"Students are also required usually in their sophomore year to take a course on engineering ethics that is taught by our philosophy department" [Int 06]*
Boss or supervisor	A student's boss or supervisor is the one who teaches them ethics	*"In a job setting, I would hope that they would learn it by working with a competent supervisor" [Int 17]*
Guest speaker	A guest speaker visiting a class teaches ethics	*"They also have like a series of guest speakers every year and pretty high profile engineering ethics speakers." [Int 14]* *"We also have a required seminar that all undergrads go to. We use the seminar as another way to say that **they're doing it this way from speakers**. It's a little backwards. ABET is a little tricky in terms of what you're supposed to show for data in terms of outcomes versus I forgot what the other term is." [Int 17]*

This area reveals lessons about the delegation and onus of teaching responsibility in engineering programs. First, there are the models that focus on individuals within the department. Next, there are models that are external to the department but still internal to the university. Finally, there are models that depend upon individuals outside the university. As with other areas, this raises the question of consistency in messaging to students about engineering ethics. There is also a cautiously optimistic note here. On the positive end, students *could* be learning ethics from several different people (i.e., the "It takes a village" model) and learning multiple perspectives. On the negative end, each potential teacher in those models could assume someone else will teach it, leaving nobody to teach it in the end (i.e., similar to the "Pass the buck" model in area 4 – where students learn).

There are two potentially troublesome trends here, both related to department hiring and resource allocation. These come from the "adjunct", "seasoned veteran", and "outsourcing" models. The "seasoned veteran" model relies upon people with professional practice experience on the faculty. That is fine if departments hire those individuals; however, if departments prioritize hiring individuals with research experience over professional practice experience then that leaves nobody qualified to teach ethics (under that model).

With the "adjunct" and "outsourcing" models, there is an implicit message about priorities and budgets, since each model may require specific funds to support those models. Either an adjunct would need to be hired or another department would need to receive some funding to support their instructor. In either case, there is vulnerability to that funding going away. In that scenario, as with the seasoned veteran model, the question arises: who will fill in the gap? If the "laissez-faire" model is also in use then this could create a gap in the department's ethics curriculum. There is another note about who teaches ethics. If the engineering ethics education community is looking for consistency over time, then the adjunct model and the outsourcing models are worrisome – they are both susceptible to budgets in flux. Given the current trends in some public university funding levels and appropriations, this could have unintended consequences if departments were to start cutting the expenses associated with teaching ethics.

Area 9: How faculty members teach ethics

Area nine corresponds to how faculty members (can) teach engineering ethics. The results presented here do not extend to how others outside the university might teach engineering ethics. For many faculty members, this area on instructional processes interfaces and overlaps with each of the preceding areas in different ways. For example, if a faculty member thinks that the goal of ethics instruction (from area two) is for students to learn the codes of ethics, then their area of how faculty members teach may simply consist of memorization techniques accompanied by multiple-choice assessments. Alternatively, if a goal from area three is for students to develop as people, then area nine would have more emphasis on students discussing case studies with each other and role playing through scenarios. Table 16 shows the models for area nine.

Table 16. Models of engineering ethics instructional methods.

Model name	Model description	Representative quote
Lecture	Teaching ethics by lecturing in front of the classroom	*"I think they talked broadly and it's probably more lecture period about the whole idea of the codes of ethics and the professions and why they are there." [Int 06]* *"We were doing some of the traditional sort of lectures or lecture-style work on ethics. That didn't seem to be particularly effective. Basically students didn't consider this to be as important as their technical material." [Int 16]*
Storytelling	Teaching ethics by telling stories from work experience	*"My own experience in an ethics course is usually by storytelling and the engineers comes in and says this is what I was thinking about at that time. I realized this later, but usually the ones who came in were the ones who in a sense made the right call. Usually the ones who made the wrong call were in jail" [Int 02]*
Role playing	Teaching ethics through role playing exercises	*"Some role playing, where you have the engineer, the client, the consultant. You have different people and they have their own preferences and backgrounds." [Int 23]*
Case studies	Teaching ethics by studying and reviewing cases of ethical dilemmas	*"I did very little lecturing. When they came in they were in a small group and I would throw a case study at them." [Int 01]* *"I love to look at case studies and ask the students what do you think those engineers were thinking when they were sitting at a desk just like you" [Int 03]*
Simulation	Faculty members use computer simulation to teach ethics	*"I'm even sort of wondering if there is a way of doing simulation. Some of the more innovative things I see people do is the theater where they have presentations and try to get you into role playing and get you to feel what will maybe be a dilemma, and maybe we could go even further with simulations.* ***You're talking about either computer simulations or virtual or augmented reality sorts of situations****." [Int 16]*

Table 16 continued

Black box	Unawareness of any specific of engineering ethics education	For instruction processes: "*I don't know how you would teach it" [Int 13]*
Modeling behavior	Course instructor or manager teaches ethics by modeling ethical behavior	*"I think the way to do that is to talk about it a little bit all the time and to some extent act the part and have them see me practicing those things." [Int 24]*

The models in this area cover the gamut of how ethics can be taught in the literature. Most literature on engineering ethics pedagogy discusses these models. Here it is important to note the difference between normative and descriptive models that faculty members have. For example, a faculty member could have a descriptive mental model of the "sage on the stage" model for ethics instruction, but they may have a more normative mental model that involves more active learning through role-playing and small-group discussions. Also, these models are not models of how ethics is taught, but rather how *university faculty members* teach ethics. This means that if someone had a model in area 8 (who teaches ethics) in which a boss or supervisor teaches ethics then the corresponding model of how that person teaches ethics was not captured in the interviews.

One could also organize the models in this area by how much they emphasize the instructor's activity (high to low) and the student's activity (high to low). For example, in a lecture model, one would expect there to be high instructor activity and low student activity. In the case studies model, there might be equal levels of activity from the instructor and the students as they engage in dialogue. On the other hand, in the role playing model, there might be a range of instructor activity (reduced to moderating the activity) and high student activity. This raises the question of whether certain models are more effective or appropriate than others.

There were a few unobserved models from the literature worth noting. First, in his review of common approaches to teach ethics (published before ABET adopted EC2000), Haws (1999) mentioned service learning as a way to teach ethics. No participant mentioned this model. Second, an "UnLecture" as described in the NAE publication *Infusing Ethics into the Development of Engineers: Exemplary Education Activities and Programs,* is another example. In that model, faculty members teach by guiding students and letting them make their own choices (NAE, 2016, p. 17).

Area 10: How students learn engineering ethics

Area ten includes models of how students learn incorporates the different mechanisms and locations that describe the actual learning process that students experience to learn engineering ethics. It relates to the implicit and explicit theories that faculty members have concerning the processes behind students actually learning. Table 17 lists these models.

Table 17. Models of student learning mechanisms.

Model name	Model description	Representative quote
Practice makes perfect	Students learn ethics through repetition	*"I think the education of it is like the opportunity to practice making these kinds of decisions." [Int 11]*
Role models	Students learn through observing and modeling behavior of others	*"[It is] not through any sort of deliberate instruction by their work supervisor but more by exposure to these people in Industry that try to model their behavior" [Int 02]*
Nature over nurture	Students learn ethics by being born with it	*"When I think about engineering ethics, I just think, well, it's just kind of like ethics, right? It's just the ethical thing. Why would you do something, you know, not ethical? …[It's] somewhat innate I guess." [Int 19]*
Training wheels	Students gain experience reasoning through ethical dilemmas in a low-risk environment	Teaching ethics this way involves *"putting students into an environment where they actually have to consider the ethical dilemma and have the feeling of conflict internally that you would have perhaps if you get into a situation where you're now working for a company and they're doing something" [Int 16].*
Learn through experience	You have to experience it out in practice rather than learning ethics in the classroom	*"I'm a little concerned that maybe it's something that you almost have to experience in order for you to learn it" [Int 13]* *"I think the vast majority I'd say learn it on the job and hopefully they learn it from good people that they're working with" [Int 07]* *"I'm thinking they learn it when they start working and they have all the pressures on them…That's when they really learn their ethics." [Int 10]*

Table 17 continued

Pre-collegiate model (the ship has sailed)	Students learning ethics before they arrive on campus	*"I think a lot is that their like ethical frameworks are developed before they come to us. Something to think about, like personal ethics. And I think that that often does play a role in their views and perspectives on engineering ethics. I think that's probably the biggest one. Uh, just most likely like family and I guess like friends or extracurricular experiences." [Int 14]*
Osmosis	Students learn by observing and being around ethical people	*"they probably don't get any formal education there on ethics but hopefully they kind of are getting a little bit of it through* ***osmosis****, seeing how people interact and how they act and some of the standards that seem to be in place at the different workplaces." [Int 13]* (emphasis added) *"mostly they would be drawing on unconscious learning or people are telegraphing what they read one place one time. The sense they get from people around them. I think a lot of its going to happen like that." [Int 25]*
Learn through failure	Students learn from their mistakes	*"In a job setting, I would hope that they would learn it by working with a competent supervisor,* ***and I think almost every student learns through failure****." [Int 17]* (emphasis added)
Learning by doing	Students learn by working through dilemmas in courses and extracurricular activities	*"For engineering, they learn anything by doing, so they want to do something. You can't really just talk their ears off on engineering ethics. So if they are in a situation where they have to make those decisions and I gave the example like a project or a competition, those are situations where they will become memorable for them." [Int 23]*
	Unobserved models	
Black box	Unawareness of any specific of engineering ethics education	

The models in this area again offer general lessons for potential mental models that faculty members have of student learning processes in subjects beyond engineering ethics alone. There is also a spectrum for how active the student is in each of these models. In the "role model" and "osmosis" mental models there is an implied subconscious learning mechanism. In the "nature versus nurture" model there is even less room for input from the environment. On the other end, "practice makes perfect" is an active model that requires students to reason through multiple scenarios until they can effectively and appropriately work through the entire problem. Even among student activities, Whitbeck (1995) suggests that not all student activity is equal. There is a difference between having students as moral agents and students as judges, and acting as agents is more effective than acting as judges.

Similarly, some of these models also require auxiliary information for the student to learn. It may not be enough just to design courses that give students experiences. Instead, those courses need more structure and information exchange between the students and the instructor. For example, in the "learning from failure" model there is an implied feedback loop to enable the student to avoid making the same mistake(s) in the future. Without that feedback, there is no reason to believe effective learning would subsequently occur.

There was also variability in how much these experiences can be designed for students. In the "nature versus nurture" model there is little room for learning experiences in the classroom. In the "learning by doing" or "training wheels" models there is ample room for course design to make a difference. The latter models require the student to be placed into a scenario where they have to analyze the issues and arrive at a decision. This is hard to accomplish without intentionally creating those scenarios for students. Relying on happenstance for students to encounter those on their own is a dubious strategy if one's goal is for students to learn engineering ethics.

Discussion

As anticipated, the mental models of faculty members varied across numerous dimensions, exhibiting many common elements but also key differences that may affect pedagogical and curricular decisions. By breaking those models down into the system's state, form, function, and purpose – consistent with the definition of mental models – we can see the diversity of models that faculty members have in each of these areas. When taken together, it is no wonder that there exists so much room for improvement in engineering ethics education.

Of note for the larger engineering education community, some of these differences among models are not specific to engineering ethics education and instead apply more broadly to the entire engineering education system, i.e., area seven on who makes pedagogical and curricular decisions. This observation highlights this study's relevance and importance for educators and researchers interested in other areas of engineering education beyond engineering ethics education. In the following sections I discuss key points across multiple areas, future work, limitations, and a note on unobserved models.

Looking across areas

One of the most notable features of many mental models across the areas, regardless of specific discipline, is the role of accreditation. Specific student outcomes were often mentioned as a motivating factor for including ethics in the engineering curriculum. Although other justifications were also given for teaching engineering ethics, one cannot understate the importance and relevance of ABET accreditation standards. The most explicit area that accreditation affected was area 3 (the goals of ethics instruction). The "check the ABET box" model subsequently informed who was making decisions (e.g., the department's ABET review committee), who was teaching ethics (e.g., the person assigned to teach it), and how/when it was taught (e.g., whatever would satisfy ABET). For better or worse, ABET permeated many mental models in some way, despite the fact that ABET merely sets a floor for a minimum emphasis on ethics and says nothing about the specific of ethics education.

Another common element in the mental models was the role of work experience in one's mental model of engineering ethics education. This applied from both the side of those who had substantial work experience as well as for those without such experience who nevertheless imputed certain characteristics and responsibilities to faculty members in their respective departments who did have such experience. For example, some faculty members had the "seasoned veteran" model of who teaches ethics (especially as a normative model in that area, suggesting the faculty with work experience *should* be the ones teaching ethics). Work experience was often referenced as a source of stories to share in one's courses, regardless of whether that faculty member was teaching a course assigned to teach ethics for ABET-accreditation purposes. Those faculty members also were deemed to have the attention of students because they had the "horror stories" [Int 01, 25] to get students' attention.

The lack of centralized planning was a third element throughout the mental models regardless of discipline. There seems to be only a minimal place in the mental models for central coordinating efforts that could infringe upon a faculty member's academic freedom in the classroom. This curricular decentralization in engineering education can be both a blessing and a curse. On the one hand, it can lead to "pockets of innovation" [Int 03] because faculty members have the freedom to try new strategies or incorporate new material into their courses. On the other hand, there may be no discernible coordination between faculty members, which manifests as a disjointed curriculum and suboptimal learning experience for students. That state of discoordination also reflects how engineering education governs itself (Akera, 2016).

The underdevelopment of models is another important topic across the areas. For example, when specifically asked about how students learn engineering ethics, participants first described general activities that students may complete in their courses of study. When asked for elaboration on what actually happens and how these activities may lead to students learning, only two of the participants in the study were able to identify specific theories of learning or moral development. This might be explained by their training in a formal education program. Aside from those two unique participants who may have seen these ideas while they themselves were students, there was minimal elaboration on what internally happens for students as a consequence of those learning experiences.

Looking across the areas for a single faculty member also revealed larger patterns in faculty members' mental models. In particular, there was a degree of consistency. For example, some participants whose models of the content and definition of ethics revolved around professional practice also had models of teaching and learning that relied on industry practice (e.g., internships, on the job training). Other participants whose models of teaching involved active learning also described more active roles of faculty members in other areas like area seven (who makes decisions). In other words, it might be possible to encapsulate the multiple areas of a mental model under a larger theme that permeates throughout each area. The degree to which faculty members exhibit consistent themes across their mental models' areas is a question for future work.

Future directions

How faculty members' specific mental models of teaching and learning inform their pedagogical choices is an exciting area for future research because there is very little known about this topic. For anyone interested in changing engineering curricula, this is an important area to address. Strategically, it also provides a point of discussion since prior research suggests that faculty member beliefs (hypothetically embedded in their mental models) inform their pedagogical decisions (Fang, 1996). There is also a big open question of how and whether certain models of student learning correspond to specific pedagogical approaches.

In the future it will be helpful to investigate the correlation between these models and faculty member decision-making. The present study hinted at certain environmental and personal factors that influence mental models, but the link between mental models and specific decisions was left unexplored. This is an exciting area for researchers to pursue because it may highlight links between experience, environment, mental models, and observed decision-making behavior. This can be operationalized in research by looking at specific areas, specific dimensions, and/or specific model types mentioned earlier in the findings.

There are also a number of aspects of the mental models that extend to other areas of the engineering education system. These include: the role of hiring practices, the role of individual efforts and faculty members championing a cause, and commonly cite constraints to change (e.g., personal time, course-hour constraints, funding, priorities, interest, etc.). Given the prominence of these constraints, it could be fruitful to study more closely the relationships that dictate how these constraints are formed and how resource allocation decisions affect engineering education more generally.

Of interest to the broader engineering education research community, the models in areas 6, 8, and 10 can provide insight into general features of undergraduate engineering programs and faculty members. The structure of programs, the nature of decision-making, and models of student learning are all relevant across sundry areas in engineering education research. The language and models here can therefore be useful to account for in other areas of inquiry.

Limitations

One major limitation from this study comes from the sampling method. In particular, the participants almost unanimously were members of ASEE, which arguably signals their interest in engineering education, even if it does not signify anything in particular about their interests in engineering ethics education. This may not be an accurate representation of engineering faculty writ large. This is not anticipated to be too detrimental to this study since some of the members exhibited the same relatively sparse mental models that one would anticipate finding in the average faculty member.

A second major limitation of this study is the occasional equivocation between positive and normative mental models that faculty members may have. The interview questions did not always distinguish between how much a faculty member may be reporting about their own experiences or the structure of their department's ethics education scheme vis-a-vis what they believed their program should do. Insofar as their mental models influence their own pedagogical and curricular decisions, this study could have homed in on their mental models of decision-making as teachers rather than their mental models of the overall ethics education establishment.

Third, on a philosophical level, there is no direct evidence of the stability of these mental models. In particular, it is possible that the mental models elicited during the interviews are distinct from those enacted during specific situations involving engineering ethics education. This study was not designed to differentiate between elicited models and situation-dependent models utilized at the time and point of action. Investigating this possibility might require administering the same interview protocol at two separate time points for each participant.

Fourth, there is need for caution when interpreting the stability of these mental models. There is no definite indication from the interviews alone of the tractability of these mental models. In particular, it is difficult to gauge how amenable these models are to changes. For example, if a faculty member attends a training seminar at an ethics institute, will their mental model of engineering ethics education have change afterward? Mental models research in areas like risk communication is predicated on the idea that educational efforts can change mental models, so this is not considered a significant concern here.

A note on unobserved models in any area

As mentioned in the methods section, the sample size of 25 faculty members was anticipated to reach conceptual saturation based on prior research using this mental models methodology. Although this was generally true – coding for the final few interviews did not produce updates to the codebook – it was possible to envision a few alternative models in some of the areas that went unobserved among the sample. For example, there were few, if any, models that were skeptical, oblivious, adversarial towards engineering ethics education in general. This may be because nobody truly has mental models based in those beliefs or because faculty members with such models would not volunteer to participate in a study explicitly about engineering ethics education.

Conclusion

This study helps characterize the space of mental models of the engineering ethics education system that faculty members can have. Just as there is large variation in how and how much undergraduate engineering programs teach engineering ethics in their curricula, there is a correspondingly wide spectrum of mental models that faculty members can possess of the engineering ethics education system. Points of similarity among the models include the role of ABET in motivating programmatic decisions, a sense of normative responsibility to teach ethics, and the importance of work experience to increase propensity to teach engineering ethics. Given the trend to hire fewer tenure track candidates with substantial work experience that some participants reported, this could be a troubling trend to track if departments continue strategically hiring faculty members for their research experience and ability to generate research funding as an alternative revenue stream. Points of divergence in the mental models included best practices, optimal time for teaching engineering ethics, and even the fundamental definition of engineering ethics, which subsequently guides the entire enterprise of engineering ethics education.

The work also demonstrates the use of a methodology for studying faculty members. This use is a contribution to the system dynamics literature because it offers a novel system for applying this method. It is also a contribution to the education literature because the results underscore the importance of accounting for both structure and agency when looking at curricular and pedagogical decisions in courses and programs. That message was particularly salient given the observed (and expected) effects of environmental context in shaping the contents of faculty members' mental models.

Finally, the results of this study can inform future work on a larger, national scale using a survey instrument functioning as a confirmatory questionnaire to identify prevalence of certain mental models as well as correlations among some of the specific mental model components and factors like specific engineering discipline, faculty work experience, personal educational background, and their main types of courses taught. For example, is there a consistent pattern that years of work experience is positively correlated with a likelihood to incorporate engineering ethics in one's classes? Does the concept of licensing appear more frequently in civil engineering faculty members' mental models of engineering ethics when compared with mental models of electrical engineering faculty members? All of these are exciting questions for the engineering education community to consider not only as they pertain to engineering ethics but also insofar as they extend to sundry areas throughout engineering education.

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CHAPTER 4: CONSEQUENCES OF THE POLITICAL ECONOMY OF ENGINEERING EDUCATION

Preface

There are myriad social, political, and economic factors that affect decision-making processes in and around engineering education. Although the education community may study those processes and their effects using a variety of quantitative and qualitative research methods, there is a hitherto under-utilized framework at our disposal: that of political economy. In particular, using concepts and tools from political economy can help clarify aspects of the engineering education system that many researchers may already indirectly sense by providing precise language and analytical formalisms to more directly describe and explain those aspects. By focusing on the political economy of engineering education, researchers, faculty members, and/or administrators can have a new set of conceptual tools at their disposal for studying, analyzing, and changing the system.

Introduction

During an address at the National Academy of Engineering, MIT President Charles Vest (1995) drew attention to a simple fact: engineering education is continuously shaped by social, political, and economic factors. More specifically, higher education is subject to the forces of political economy – a term used to describe "the study of the social relations, particularly the power relations, that mutually constitute the production, distribution, and consumption of resources" (Mosco, 2009, p. 24). The focus on these social relations is part of what differentiates political economy from traditional economics (which would tend abstract those social relations away) (Drazen, 2002, p. 5). Those social relations can be among different units of analysis, from governments, organizations, groups of people, or families (Arndt, 1983). In the *Oxford Handbook of Political Economy*, Weingast and Wittman (2006, p. 4) underscore the flexibility of this political economy framework to consider different units of analysis and enable methodological heterogeneity. For example, applied to public education, political economy might consider how cycles of 'economic austerity' affect public funding of higher education (Carpentier, 2015), or how schooling reproduces class structures (Bowles & Gintis, 1977; Brint & Karabel, 1989). We can apply this framework to engineering education systems to provide insight into the professional formation of engineers. Those engineers are then in situations to make decisions that affect the public in myriad ways, which underscores the importance of how they learn to make decisions in their careers.

How does this political economy approach apply to engineering education? I suggest that *the political economy of engineering education is the constellation of* ***power relations*** *that determine* ***resource allocation*** *in engineering programs*. It is about understanding how groups of people both external to the university – e.g., government officials, industry representatives, the public – *and* internal to the university – e.g., administrators, faculty members, students – interact and make decisions about resources – e.g., time, money, energy, space – in engineering education. There are clearly numerous dimensions to consider when characterizing the political economy of engineering education. I have illustrated the various moving pieces – level of analysis, unit of analysis, social relations, and resources – in Figure 12.

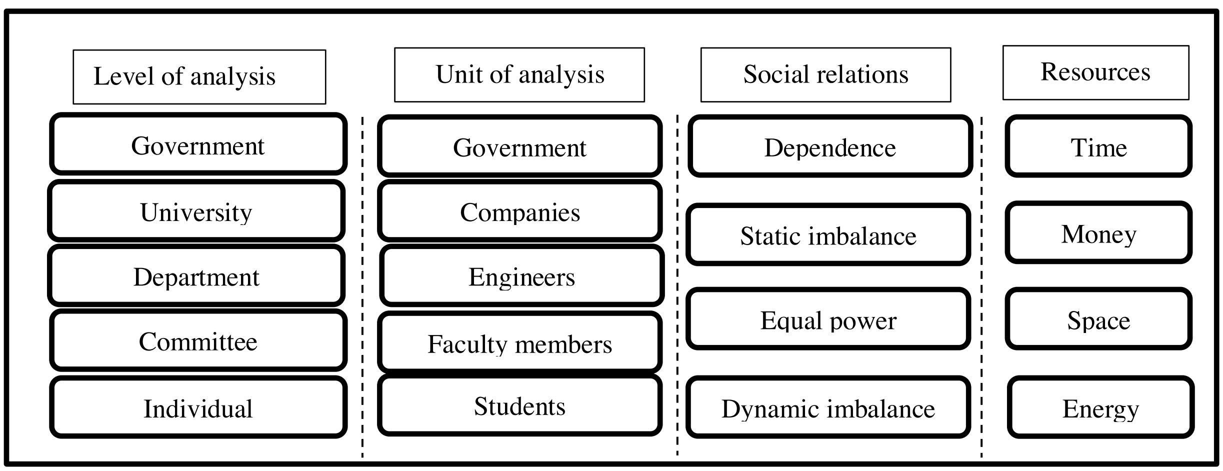

Figure 12. Dimensions and example variables to consider in study of political economy of engineering education.

With the preceding definition, studying the political economy of engineering education should therefore have two focal points: (1) social relations (especially power relations) among groups of people involved in the engineering education system and (2) resource allocation. Example questions to ask about the political economy of engineering include: How do state and federal governments appropriate funds for research that universities and faculty members compete for? How do those antecedent governmental decisions shape the subsequent relationships among faculty and universities when they compete for those limited resources? How do faculty members on search committees in engineering departments decide upon whom to hire (a human resource decision), and what informs their hiring priorities? How does a curriculum committee incorporate feedback from industrial advisory boards, alumni, current students, and the surrounding community to determine how to allocate time in the curriculum? In each of these examples, social relationships and processes determine resource allocations decisions.

In order to elaborate upon this definition for the political economy of engineering education, I created a conceptual model, illustrated in Figure 13. The model starts at the bottom of the figure with observable phenomena. The phenomena offer a window for viewing pivotal interactions and social relations in the engineering education system. Through these social relations, groups of people interact and make resource allocation decisions. Those resource allocations then create the setting and circumstances for new phenomena because other people will depend upon those resources. The new phenomena can be at the same or different levels of analysis (e.g., starting at the university level and ending in the classroom level) and/or in a different environment (e.g., internal to the university instead of external to the university). With these new phenomena, the cascade can start over again, shaping subsequent social relations among different groups that make new resource allocation decisions, which affect the same or even new groups of people. The cycle can continue through myriad iterations; Figure 13 merely shows a simplified version of this process.

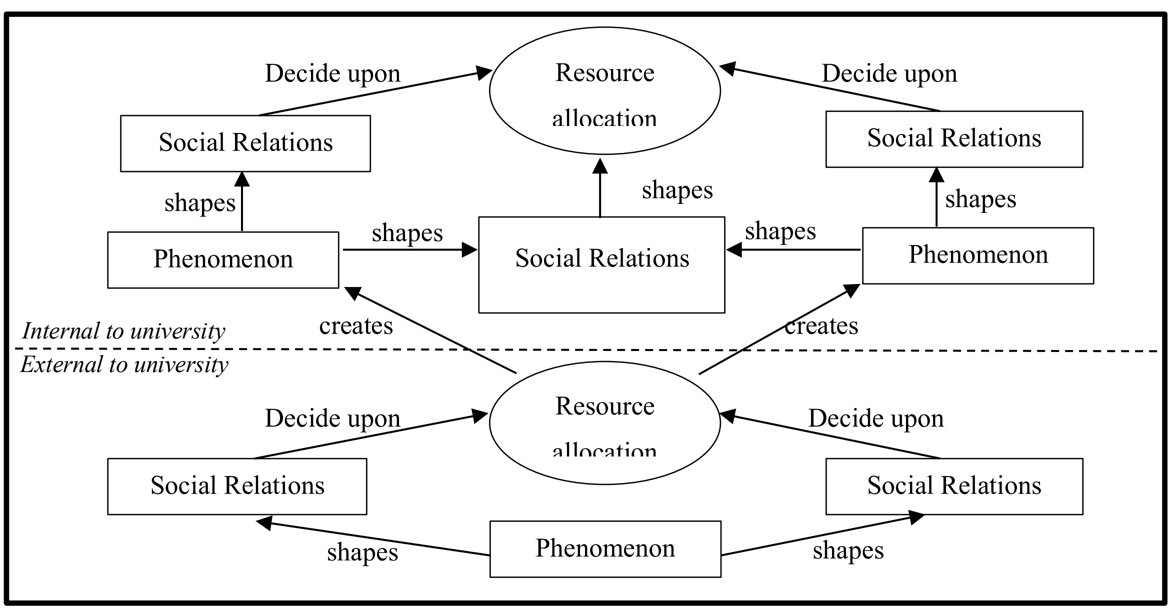

Figure 13. Connections between phenomena, social relations, and resource allocation.

For an alternative depiction, Figure 14 shows this same conceptual model *but with the modification of rendering the phenomena as windows through which we can see social relations affecting resource allocation decisions*. In this picture, the phenomena can transpire within or outside of the university and at different levels – e.g., governmental, industrial sector, or department. Again, the people and groups interacting with each other in social relationships make resource allocation decisions. The resource allocation decisions then influence (illustrated with dashed arrows) subsequent phenomena. With these subsequent phenomena, the pattern repeats, providing new windows into more social relations among people making resource allocation decisions. Notably, this is a simplified depiction of the conceptual model that omits social relations across the different levels. The main purposes of the figure are to highlight: (1) how the phenomena function as windows into the political economy of engineering education, (2) how social relations affect resource allocation, which can then influence subsequent phenomena, and (3) how these different levels may interact within the larger engineering education ecosystem and be relevant to the overall political economy of engineering education.

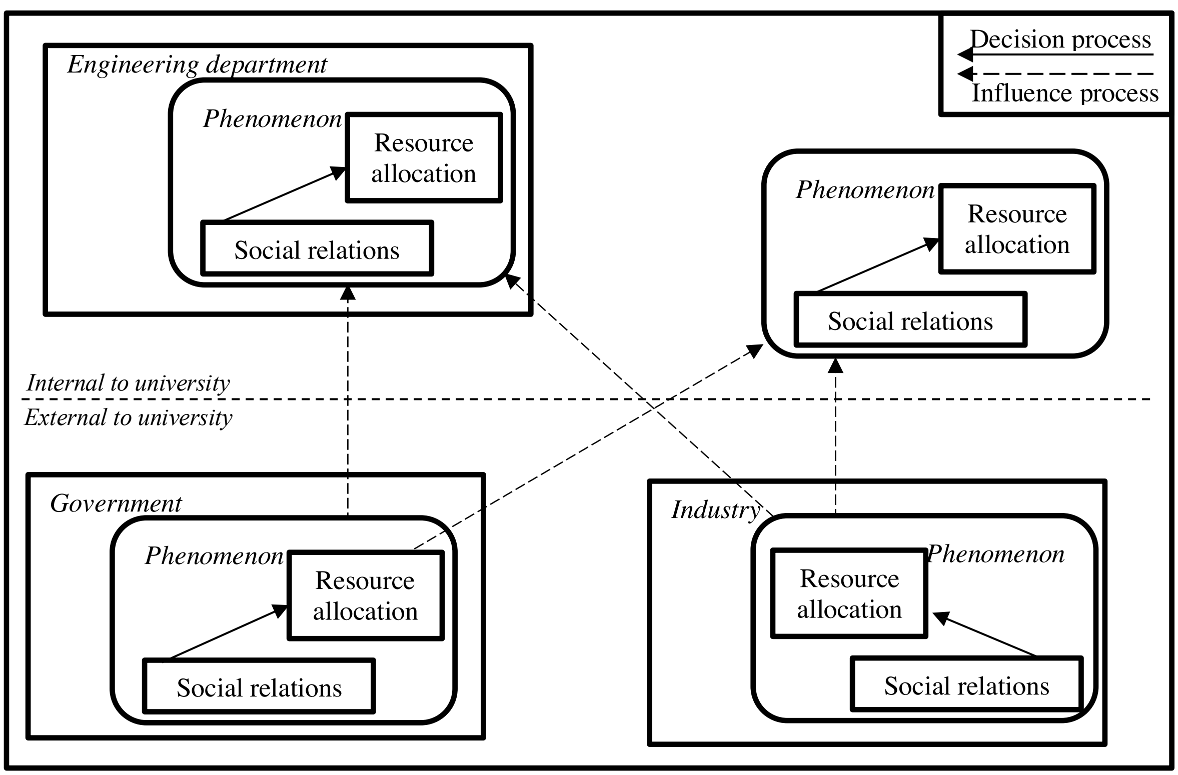

Figure 14. Conceptual model of political economy of engineering education highlighting the role of phenomena as windows into social relations and resource allocation.

As defined earlier, research on the political economy of engineering education will consider (1) the power relations and dynamics informing decisions on (2) resource allocation in engineering education organizations. This is important for anyone impacted by these education systems because it highlights factors that may be overtly or subconsciously influencing decisions that directly affect the formation of future engineers. This is important for researchers because it provides a set of constructs for framing problems. It is important for administrators because it helps identify root causes of issues that they face in their jobs. It is important for reformers because it suggests why some of the attempted or contemplated remedies to problems in the system may be ineffectual or, alternatively, may work. In other words, studying the political economy of engineering education offers tools for everyone involved in the system to address the problem of how to understand (and change) the behaviors and decision-making processes that they observe among participants in engineering education.

These behaviors, decision-making processes, and factors run the gamut and can include things like curriculum committees' approval of a mandatory undergraduate class on engineering ethics and budget decisions that college administrators make about specific programs. Even though it often goes without direct attention, the confluence of these social, political, and/or economic factors has been influencing engineering education for almost a century, as Table 18 illustrates with examples of national reports dating back to 1930. These national reports come from organizations including the American Society for Engineering Education (ASEE), the Engineers' Council on Professional Development (ECPD), and the National Academy of Engineering (NAE).

To anyone participating in the engineering education system – e.g., faculty members, students, college administrators, government officials, or professional engineers – Vest's observation may sound trite. For example, one might think: sure, budgetary constraints limit the kinds of student support programs that a campus teaching and learning center can offer (Frantz, Beebe, Horvath, Canales, & Swee, 2004); or yes, the interpersonal dynamics between faculty members can create a hostile environment for other faculty members in the department (Campbell & O'Meara, 2013; Committee on Science, Engineering, and Public Policy (U.S.), 2006); or okay, I can see how accreditation bodies inform specific curricular and pedagogical decisions that faculty members make (Lattuca, Terenzini, & Volkwein, 2006); or of course, a university's board of governors might want to influence curricular decisions (Kosak et al., 2004). Yet, when stepping back to consider each of these examples in unison, Vest's clichéd observation also becomes one that describes a formidable reality permeating higher education and engineering education. Namely, there really are social, political, and economic factors contributing to the political economy of engineering education, affecting behavior throughout the education system.

A political economic analysis enables us to examine the root causes of observed phenomena in engineering education. Political economy has the power to connect our understanding of these phenomena in a holistic way rather than seeing them as isolated decisions. This is in part because, although social, political, and economic factors affect decision-making processes and behavior throughout engineering education systems, there has not been a concerted and sustained examination of the political economy of engineering education to date, possibly as part of a broader ideology of depoliticization in engineering that extends to engineering education (Cech, 2013; Cech & Sherick, 2015). Hence, there are gaps among (a) the observations and experiences that we have of political economic phenomena affecting engineering education systems, (b) how we think about those phenomena, and (c) what we can ultimately do to perpetuate or change conditions that engender those phenomena (them).

The three-part disconnect between observations, analysis, and action underscores a particular problem facing the engineering education community. Namely, specific phenomena may affect individuals and groups in the system and, even if we can sense that a problematic situation exists, we do not use the analytical lens to frame the underlying political economy. There is space for improving how we analyze the engineering education ecosystem, which raises the logical question*: what are some conceptual frameworks that we can use to understand aspects of the political economy of engineering education?* This paper answers that question by pointing to multiple observable phenomena among engineers, engineering educators, administrators and their associated premises.

Purpose and format

The goal in this work is to introduce ideas from political economy for understanding engineering education in general and engineering ethics education in particular. The political economy of engineering education often only receives nominal attention in association with topics of interest throughout engineering education; however, making the political economy of engineering education more explicit can help the engineering education community in part through the effects of naming. The act of naming is powerful, whether it relates to negotiating objectives among individuals (Merry, 1990) or simply identifying aspects of our environment by naming our surroundings and thereby creating common ground (Milstein, 2011). Giving the engineering education community the lexicon and shared mental models can help them analyze some of the associated phenomena more effectively. With these tool in mind, participants in the system will be better equipped to bridge the three-part disconnect between their own experiences, how they process those experiences, and what they can do about the root causes of those experiences. I take engineering ethics education as the paradigm case for observing the effects of political economy on the engineering education system in order to help answer the overarching question in this dissertation – how can we understand the state of U.S. engineering ethics education? The answer from this chapter: we can understand that state by looking at the power relations that affect the allocation of curriculum time, faculty time, student time, and department budgets.

In order to introduce ideas from political economy for understanding engineering education, I begin by reviewing prior published statements that allude to the political economy of engineering education without naming it as such. This review establishes the persistence of social relations affecting resource allocation in engineering education over time, even though they hitherto have rarely been labeled as the "political economy of engineering education."

Finally, with that groundwork laid, I discuss how a phenomena-based approach to characterizing the political economy of engineering education can help researchers connect observed experiences with root causes of topics throughout the engineering education system. I take engineering ethics education as an example here and use these concepts to illuminate answers to the question of how to understand the state of U.S. engineering ethics education. I offer ways to interpret, articulate, and research the political economy of engineering education by using a three-step process:

(i) Review a common phenomenon in the traditional study of political economy.

(ii) Provide demonstrative quotes from faculty members that highlight the relevance of that phenomenon in engineering education. (NB: the quotes stem from 25 interviews of faculty members at 21 different universities in the U.S. that highlight the relevance of each phenomenon within engineering education.)

(iii) List sample research questions that combine the concept with a specific aspect of engineering education. These questions are intended for anyone interested in advancing an understanding of some dimension of the political economy of engineering education.

Through this process, my goal is to identify and describe six relevant areas within engineering education where ideas of political economy pertain to engineering ethics education, showing how power relations determine resource use in the engineering education system. By the end, the reader should feel equipped to span the spaces between some of their lived experiences in an area of the engineering education system, how they cognitively process those experiences, and where the community might start to improve the system for educating engineers. Lattuca and Stark's (2009) academic plan model, discussed in chapter three, depicts this system and the interpersonal factors that can affect curricular and pedagogical decisions in engineering departments.

To emphasize a point made in the first paragraphs above, although the ideas that I review in this paper can all focus on the engineering education system, they vary in their level of analysis within that system. For example, some ideas focus on individual actors – students, faculty members, department chairs, etc. Other ideas look more at organizations – departments, colleges, universities, professional societies, government agencies – or the environment external to engineering education – private industry or governments. Furthermore, not only do the ideas vary in their prescribed level of analysis, but they also range in applicability across settings. Some ideas may obtain in smaller departments at private universities (or, conversely, large departments in multiversity settings) while other ideas may apply equally well in many different organizational contexts. This variety in level of analysis and applicability should help these ideas appeal to a broad audience, allowing readers across the spectrum to find something meaningful they can apply in their own work, wherever they are.

Reviewing literature around the political economy of engineering education

To review prior mentions of the political economy of engineering education, it is first instructive to consider the political economy of higher education since engineering education is part of that higher education system. Therefore, I begin with a brief review of the political economy of higher education before proceeding to a more specific focus on engineering education. The engineering education review focuses on both national reports and articles where the political economy of engineering education has either received direct (less common) or indirect (more common) attention.

The political economy of higher education

The political economy of higher education affects engineering education in part by forming the larger structure within which engineering education operates. Metaphorically, it forms the waters in which engineering education swims. Likewise, by extension, it forms the water in which engineering ethics education swims. The basic premise is simple: engineering ethics education is part of engineering education, which is part of higher education. Since the higher education system has myriad power relations that implicate resource allocation within the system, one should first consider that political economy of higher education in order to understand engineering education.

The current political economy of higher education is best understood in the context of a post-1970 neoliberal shift in economic paradigms. Neoliberalism is a political economic philosophy that combines a classical economic emphasis on free market exchange with a liberal political philosophy that prioritizes liberty (Harvey, 2005). That conception of liberty is often biased toward a version of negatively liberty defined by an absence of bodily interference rather than a more capacious positive liberty characterized by the presence of opportunity and options (Berlin, 1969). From an ideological perspective, this paradigm shift is fundamental because neoliberalism normatively prescribes a minimal role of state intervention in all aspects of life, including education (Connell, 2013). In place of governmental programs supporting public interest projects in the name of the public good, the market is assumed to achieve 'efficient' outcomes, often nebulously defined or assumed.

Under the grip of this philosophy, the political economy of higher education subsumes topics like academic capitalism (Münch, 2014; Slaughter & Leslie, 1997), state funding cuts (Li, 2017), education financing (Garritzmann, 2016), universities behaving like corporations (Washburn, 2005), replacing the notions of education as for the public good with private good (Williams, 2016), students being treated like consumers (Bunce, Baird, & Jones, 2017), and other market-like behavior in higher education (Leslie & Johnson, 1974; Newman & Jahdi, 2009). As Slaughter and Leslie (2001) define it, academic capitalism consists of behaviors from university faculty and administrators to compete for limited financial resources (e.g., funding). The rise in academic capitalism corresponds with the decrease in public funding as governments shift to a private model in education (Geiger, 2011; Teixeira & Dill, 2011). Shifting toward academic capitalism pursuant to changes in government funding and public support consequently determines how faculty members allocate their time (Liefner, 2003; Taylor, 2001). Importantly, there is little reason to believe engineering education is immune to these trends in the political economy of higher education.

Taken together, the scenario depicted is a simple one: governments withdraw funding for higher education in the name of austerity (McLendon, Hearn, & Mokher, 2009) and free market competition (Leslie &Johnson, 1974) coupled with an argument that the state has no place in supporting higher education (Archibald &Feldman, 2010). Amidst this backdrop, the political economy of engineering education exists. Departments compete for funding from colleges and university administration. These departments also hire faculty members who can bring in funding to help fill the gap left from states reducing their funding appropriations. Faculty members then compete for research funding to supplement constricted budgets. The shrinking budgets then shape other decisions among actors in engineering education systems. Overall, the political economic environment creates dynamics among actors in the system where the market logic eventually begins to dominate and shape decisions throughout the system. *This need not be the case*. Those choices are not predetermined. These are choices in engineering education that arise from other choices in higher education, which likewise arise from choices outside higher education. Options exist, but availing ourselves of them would require deviating from our current trajectory and getting out from under the spell of the prevailing mode of market-based logic.

The political economy of engineering education

Prior work related to the political economy of engineering education has frequently involved either specific studies on one aspect of the engineering education system or generic observations about the relationship between engineering education and social, political, and/or economic factor(s). We will consider several examples below that can help demonstrate the ways in which the political economy of engineering education has appeared in writing, often without specifically being named as such, despite its persistent presence in the background.

Although the current paper is styled as a review of tools for members of the engineering education community and a foray into a novel area of research, prior work has looked at some of these discrete issues before. For example, Noble (1979) argued that the American engineering education system was created to serve American corporate and economic interests. Layton (1971) discussed a similarly close connection between engineering and corporate interests (with less of a focus on education). In each case, economic circumstances facing industry reverberated into how engineers were educated. Multiple other authors have looked at similar connections between engineering and corporate interests (Carlson, 1988; Veblen, 1965; Zussman, 1985). Rather than looking at strictly industrial influence, Lucena (2005) looked at the effects of national policy initiatives in the defense industry in the name of military protectionism and how *those* permeated through engineering education. In each case, authors examined the extant relationships in engineering and how their roles in the economic order of a society can and do shape decisions in engineering education.

I suggest that there is fruitful ground in this area to continue applying a political economic analysis to engineering education. The ideas in such an approach can lay foundations for an area of research focused on organizational and institutional dynamics and change within engineering education. In the past, the engineering education community has discussed departmental and institutional change from: top-down approaches and emergent approaches at both the structural and individual levels (Besterfield-Sacre, Cox, Borrego, Beddoes, & Zhu, 2014; Henderson, Beach, & Finkelstein, 2011); curricular change as an iterative process involving multiple stakeholders and incentives to ensure institutionalization (Clark, Froyd, Merton, & Richardson, 2004); and a larger culture of innovation in education through improved resources, workloads, and rewards (Jamieson & Lohmann, 2009). Despite these kinds of prior publications, the community could benefit from a more sustained focus and refined frameworks to diagnose the dynamics and improve the conditions in engineering education systems.

Within the engineering education literature, journal articles and national reports periodically contain allusions to the political economy of engineering education without using that terminology. These are some of the social, political, and economic factors that Vest referenced. Historically, the reports and articles have ranged in their focal topic from curriculum to incentive structures and many other subjects in between. I will review some of these publications in order to highlight the relevance of the political economy framing for the engineering education community. The underlying theme in these examples is that the engineering education community already recognizes some of these factors at play in the system.

Reports

Allusions to the political economy of engineering education abound in national reports on engineering education that have spanned the past century. The examples in Table 18 illustrate the sustained existence and relevance of the political economy of engineering education.

Table 18. Examples from national reports on engineering education alluding to the political economy of the engineering education system.

Source	Quote	Interpretation
Wickenden (1930)	*"Engineering education reflects our national genius for quantity production. Pressed to get a maximum result in a minimum of time, engineering educators have borrowed, half unconsciously, from the management methods of industry. The essence of the scheme consists in first visualizing the process as a whole. Then dividing it into major steps in a logical progression and finally breaking the work down into small units to be done in a definite sequence, under prearranged conditions and with the materials supplied precisely when needed and in the most convenient form, the task sequence to be carried out under close supervision, with continuous inspection and grading of piece parts, and the rewards to be paid in terms of a standard task with quality bonus." (p. 109)*	Engineering education has borrowed the Taylorist philosophy of industrial production to guide decisions in engineering programs
Rising above the Gathering Storm (Committee on Prospering in the Global Economy of the 21st Century (U.S.) & Committee on Science, Engineering, and Public Policy (U.S.), 2007)	*"Our culture has always considered higher education a public good—or at least we have seemed to do so…Now, however, funding for state universities is dwindling, tuition is rising, and students are borrowing more than they receive in grants. These seem to be indications that our society increasingly sees higher education as a private good, of value only to the individual receiving it." (p. 31)*	Shifts from viewing higher education as a public good to a private good, reflected in funding levels and public attitudes, which is consistent with larger political economic trends to reduce public spending in favor of private funding through market competition.

Table 18 continued

***Phase I Report* (ASEE, 2014)**	*"One respondent noted that there is a market for universities to help teach engineers business skills and provide lower cost options than business school." (p. 17)*	Curricular decisions being influenced by supply and demand due to market relationships of exchange established between engineering departments and employers as well as increased expectations of graduating engineers to be ready for market competition upon graduation.

The role of industry in these reports is another aspect of the political economy of engineering education . Starting with the composition of report committees. The 1985 National Academies report from the Committee on the Education and Utilization of the Engineer "consisted of 26 members and 9 panels with more than 50 additional people drawn from business, industry, and education" (National Research Council, 1985). The same is true of other reports, whether it is CEOs of Fortune 100 companies in *Rising Above the Gathering Storm* (p. ix) or corporate representatives with various titles in *Educating the Engineer of 2020* (p. 180). The pattern is familiar: economic imperatives in the form of increased international competition and threats to sustained growth – broadly portended in *A Nation at Risk* – translate into pressures on companies for skilled employees. Companies then communicate demands to engineering programs through several channels. Engineering education as a whole then responds in ways that alters decisions and behaviors among administrators, faculty, staff, and students. This is part of the political economy of engineering education.

Articles

In addition to national reports, research articles in engineering education also make allusions to political economy without naming it explicitly. These articles discuss an array of different topics in engineering education research. Those topics include curricular decision-making, faculty incentive structures, department-industry relationships, structural change, and implicit supply and demand models. Any of these articles and studies *could* link to political economic forces but they do not explicitly consider it. In other words, the analysis I propose is not just a matter of making something implicit more explicit; it's a missing analysis that has significant value. The following paragraphs review some of that literature.

Starting with ***curricular decision-making***, a 2014 study cited the importance of funding for influencing the utility value that faculty members place in their expectancy-value motivations for engaging in research-based instructional strategies (Matusovich, Paretti, McNair, & Hixson, 2014). More broadly, Watson called for a more efficient use of resources when translating research into practice for future generations of engineering education (Watson, 2009). In 2010, Borrego et al. reported that department chairs cite lack of financial resources and faculty time as two reasons for poor diffusion of instructional innovations (Borrego, Froyd, & Hall, 2010). These are just a few examples of political economic factors shaping research and practices in engineering curricula.

Political economic factors also transmit signals that inform faculty decision-making. For example, Splitt (2003) discussed the role that rewards and ***incentive structures*** can play in shaping how college administrators and faculty members approach teaching. In a 2009 study of whether engineering education research constituted a discipline, community, or field, participants pointed to reward structures like tenure and research grants as significant factors in deeming engineering education a discipline (Jesiek, Newswander, & Borrego, 2009). Again, we see references to general economic factors, i.e., specific incentives, which themselves may come from universities' struggle for resources like state and federal funding.

On the social and political side, ***industry relationships*** can contribute to the shape of engineering education as Denton (1998) discussed regarding the role of departmental partnerships with government and industry as being important for determining new education standards and impactful research. Before that, Black (1994) outlined specific pressures that industry placed on engineering education, manifesting as a combination of social and economic factors that affect the system. He even explicitly named popular practices like total quality management and continuous process improvement that engineering education could use to promote change. In these scenarios, the political economic circumstances facing industry create demands that industry passes on to engineering education, which in turn influences relationships and decisions in engineering programs, departments, and classrooms. To be clear, these are not predestined relationships with foregone conclusions; rather, they are the consequence of specific political decisions and therefore support using a political economy lens.

Regarding ***change***, in a 2012 report, threats to a department's market position – a notion reflecting the broader political economy of higher education mentioned above – among other departments within the broader academic field were cited as a significant factor for driving change (Graham, 2012a). This means that departments' competition for resources was affecting decisions of whether or not it pursued changes – and which specific changes it pursued. Furthermore, when considering what determined adoption of those changes, perception and marketing were two important factors. In the absence of external funding, those adoptions often did not survive (Graham, 2012b). This demonstrates how economic factors impinging upon higher education in the guise of resource dependence and competition are directly implicated for affecting social relations in engineering education, i.e., the political economy of engineering education. It also reflects but does not explicitly name political economic assumptions that universities operate (or ought to operate) according to free market principles, even if this comes with questionable assumptions and contradictions (Torres & Schugurensky, 2002).

A ***supply and demand model*** of education is also implicit in articles about engineering education. For example, national economic competitiveness writ large has redefined the demand for desirable engineering competencies that graduates should have upon graduation (J. Lucena, Downey, Jesiek, & Elber, 2008). McMasters (2004) described this same impetus to develop human resources to meet industry's demands from the perspective of the aerospace industry. He describes "steps that we within the broader technical community (industry, government and academe) can and should take to assure an adequate future supply of well-prepared engineering graduates for the full range of employers who have need for such talent". The supposed end goal in this political economy model is job-ready engineers, achieved through a supply-and-demand relationship between governments (or industry) and engineering departments.

Despite the clear presence of social, political, and economic factors shaping manifold areas of engineering education, as noted in the preceding journal articles, we in the engineering education community do not tend to use the conceptual frameworks afforded by focusing on the political economy of engineering education. We take the first step of alluding to these factors and their effects on departments, faculty, students, courses, etc., but typically stop short of pursuing that line of thought any further. The political economy frameworks may help the engineering education community follow the path toward characterizing the system in which we operate more effectively.

A Political Economy Framework – Analytic Tools for Engineering Ethics Education

The following section describes phenomena for characterizing aspects of the political economy of engineering education that impinge upon engineering ethics education. The phenomena are intended to provide a representative, manageable list rather than an exhaustive litany of theoretically available concepts and frameworks. The scholarly community is encouraged to challenge and grow this list in future work. Sustained scholarship in this area will improve how we understand the internal and external logics, pressures (e.g., graduate more students, publish more papers, lower operating costs), incentives (e.g., increased funding, tenure, better grades), and objectives driving resource allocation (e.g., time, money, space, energy) and decision-making (broadly construed) in engineering education systems.

Conceptual tools for characterizing the political economy of engineering education and its effects on engineering ethics education

A phenomena-based approach is one way to characterize the political economy of engineering education, but it is not the only approach. Others include more theoretical or more empirical approaches. With that said, I suggest a phenomena-based approach because the phenomena provide specific vignettes for the community to identify in their own work. Phenomena in the political economy of engineering education represent a set of observable patterns and outcomes that manifest from the relationships and interactions between actors within the engineering education system. This stylized definition of phenomena derives from Bogen and Woodward's (1988, p. 317) description of phenomena from a philosophy of science perspective as consisting in a number of causal factors that generate observable data. Phenomena can range in nature from objects, states, and processes to more complex, compound functions. Thus, phenomena in the engineering education system are objects, states, and processes that generate data which a researcher (or anyone else) might observe, hence the leading definition above. The phenomena provide a window into the mechanics and/or consequences of the political economy of engineering education (shown in Figure 14 in the Introduction). It is important to note that these phenomena are *produced* rather than *pre-ordained*, meaning that they are not inevitable. In theory, there exist alternative configurations of the system in which those phenomena do no arise because actors in these governmental, industrial, and educational systems have made different decisions. This is an ambivalent note. On the one hand, it means that changes is possible. On the other hand, it means that people made choices that put us here in the first place and may continue to do so unless actual change occurs.

The relevance here of an ontological discussion about phenomena is to delineate the objects of study under the phenomenon-based approach to characterizing the political economy of engineering education. To wit, actors, relationships, and decisions in and around the engineering education system can generate observable data that represent token phenomena for researchers to study and characterize as part of this overall political economy project. The phenomenon-based approach prescribes observing specific sets of relationships and decisions in the system and how those determine resource allocation. That is the object of study. Studying these phenomena can help amass data that in turn characterize the political economy more broadly. Such a characterization can then help provide a new framework for understanding the mechanics of the system that shapes future engineers. This project can also highlight potential areas for intervention by the more reform-minded individuals.

The discussion for each phenomenon in this section begins with a definitional overview for the reader to understand the fundamental idea. Accompanying these overviews are illustrative quotes from faculty member mental models interviews in chapter three. After briefly discussing the quotes, I provide sample questions to demonstrate how the research community could sustain a more concerted project to characterize the political economy of engineering education by looking at each of the phenomena.

The quotes come from interviews with 25 engineering faculty members in civil, mechanical, and electrical engineering departments across the United States. The interviews were collected as part of a project to characterize faculty members' mental models of engineering ethics education (more details provided in chapter three). During those semi-structured interviews, a subset of questions asked about factors that affect the curricular and pedagogical choices concerning engineering ethics education in U.S. engineering programs. Participant responses to these questions revealed aspects of the political economy of engineering education. I use the interview data here for two reasons: (1) for the reader to make contact with actual examples of the effects of the political economy of engineering education and (2) to suggest that these phenomena are visible throughout the engineering education system, even when not explicitly the object of inquiry.

In total, for this section I have identified six phenomena that provide a view into the political economy of engineering education either directly or indirectly. I claim that these phenomena can arise as the consequence of larger ideologies like neoliberalism and phenomena like academic capitalism, dictating a market-oriented decision-making process. Decisions made under that pretense then have ramifications that permeate throughout engineering education, including into engineering ethics education. The identified phenomena themselves exhibit collections of social relations that influence allocation and use of certain resources. Those social relations can be among students, faculty members, departments, committees, universities, and industry. In Table 19, I present each of the six phenomena, a brief description of the phenomenon, the relevant social relations that develop with the phenomenon, and resources affected by the social relations that manifest pursuant to that phenomenon.

Table 19. Phenomena from the political economy of engineering education.

Phenomenon	Description of phenomenon	Relevant social relations*	Implicated resource(s)
1. Market-like behavior	Supply and demand model, students as consumer, marketing and recruitment	Stu-Dep; Stu-Fac; Stu-Uni; Dep-Fac	Fac time; Curriculum time; Stu time; Money
2. Competition for prestige and reputation	Programs and universities compete for prestige that enable better ability to compete for resources	Dep-Dep; Pub-Dep; FacMem-FacMem	Fac time; FacMem research budget; Dep budget
3. Outsourcing	The decision from department A to call upon department B to teach something in department A's curriculum	Dep-Dep; Comm-Dep; Dep-FacMem (e.g., adjunct faculty)	Fac time; Dep budget
4. Program governance	How engineering programs receive and maintain accreditation and approval	Dep-Eval; Dep-FacMem; FacMem-FacMem	Fac time; Curriculum time
5. Job markets and hiring	Departmental and company hiring decisions	Dep-Ind; Comm-Ind; Dep-FacMem	FacMem time; Dep budget; Curriculum time; Stu time
6. Institutional isomorphism, entrepreneurship, and inertia	How faculty members relate to each other through committees or various policies and programs	FacMem-FacMem; Dep-Dep; Uni-Dep	Fac time; Dep budget; Stu time

Table 19 continued

Abbreviations: Dep-department; Fac-faculty; Uni-university; FacMem-faculty member; Stu-student; Pub-public; Eval-accreditation evaluator; Comm-committee; Ind-industry * Relations between actors/groups/organizations in the system are depicted with a hyphen.

To be clear, many of these phenomena are the downstream consequence of upstream political choices about resource allocation that are part of the political economy of engineering education. The conceptual model in Figure 14 in the Introduction illustrates how these different levels of analysis can influence each other. The phenomena can be external or internal to the university. They can arise from governments pushing for more students to study engineering (Blackley & Howell, 2015) to drive economic innovation (Denney, 2011) and promote national economic growth (Maloney & Caicedo, 2017). On an ironic note, however, while governments may have the impetus for economic growth and competition (and pushing for certain student outcomes accordingly), they also offer limited support due to the aforementioned political economic paradigm (neoliberalism) that constrains state intervention in the education sector (Klees, 2008; Shore, 2010). As a result, things like academic capitalism becomes more prevalent in higher education (and engineering education by extension). In turn, that phenomenon of academic capitalism helps to engender some of the phenomena in this section.

There are also several candidate phenomena that further provide windows into the political economy of engineering education, albeit in less direct ways. Those phenomena, included in the supplemental information section, are: lobbying and voting, market failures, collective action, and tragedy of the commons. Both the proceeding sections and the supplemental information section follow the same format. Specifically, I present a short description of the phenomenon, how it may arise in engineering education (demonstrated through quotes from interview participants), and pose questions that would help characterizing the political economy of engineering education.

1. Market behavior

The marketization of engineering education entails the same instances in higher education writ large, viz., treating students as consumers, prioritizing mechanisms to generate funding, and generally treating engineering education as a market good – something to be produced and sold. Examples of relevant sub-phenomena under the market behavior tent include (a) marketing and recruitment and (b) supply and demand relationships. These patterns are symptomatic of a broader political economy in which the logic of markets, decentralized coordination, minimally regulated enterprise, and ostensibly free exchange predominates (Harvey, 2005). The general philosophy is one of maximizing individual freedom (a notion commonly left underdetermined (Skinner, 2003)) and the supposed best way to do this is with markets. Embedded within the broader political economic paradigm, engineering education consequently exhibits the same patterns of values and behaviors among universities, departments, students, companies, and governments. Engineering ethics may be treated as simply another item to include or exclude in the curriculum as the market demands, under this orientation. If it behooves marketing and recruitment efforts to emphasize engineering ethics then programs will incorporate ethics more intentionally, but if the converse is true then engineering ethics may never receive the overt attention that it deserves from faculty members and programs.

1.A. Marketing and recruitment

Departments specifically adopt practices to attract students into their programs, especially during moments of waning student enrollment or floundering finances. This creates specific kinds of relationships among faculty members in a department and between departments (or universities) and prospective students. As one faculty member stated

> *"we have various ideas about why we lose students and we try to kind of deal with or address those issues. So we have different activities that we host for first-year students. We look at trying to improve our presentation to the 131 class where we get our 20-minute slot… And then just general improvements to the undergrad curriculum that might be more attractive to first-year students." [Int 13].*

Another faculty member at a different university described the same marketing phenomenon in their shared introduction to engineering course:

> *"I think the overarching goal is to try and attract students to civil engineering, so trying to make civil engineering look exciting to the freshman. It is a marketing tool as much as anything" [Int 04].*

These examples suggest that the phenomenon of marketing to students for recruitment purposes is affecting decisions about time material within engineering courses, and therefore it is a relevant phenomenon to consider in characterizing the political economy of engineering education.

Sample Questions: To what degree do marketing decisions drive curricular changes in undergraduate engineering programs? To what extent does discourse about marketing of programs reveal about underlying political economic assumptions? Are there common themes in programs' marketing and recruitment efforts for attracting new students, especially ones that are systematically misleading in some way? Where, if at all, does engineering ethics receive attention amid the conversations about marketing to students and selectively representing programs? Is there a potential crowding out effect from other topics receiving more curricular time in the name of appealing to students?

1.B. Supply and demand.

The concept of supply and demand is a common fixture in microeconomics. Depending on one's perspective and unit of analysis, both supply and demand of a variety of resources can emanate from any number of actors. In the political economy of engineering education, the supply of particular courses can be influenced by demand from students, for example. Additional examples include the demand-side phenomena that originate from students and employers for certain learning opportunities to develop particular skill sets and the supply-side phenomena from faculty members and departments offering specific courses creates a general transactional arrangement in engineering curricula. Those relations among industry, students, departments, and faculty members then determine curriculum time allocation (which in turn can affect faculty and student time allocation). For example, one interview participant noted that their department will add a new course to the curriculum as the result of demand from members of the department's industrial advisory board:

> *"I think we're going to require that economics course as a direct response to what they want" [Int 17].*

Echoing this sentiment of modifying curricula to meet employers' demands, one participant stated that

> *"Engineering programs need to address the skills desired by the companies hiring their students" [Int 10].*

Similarly,

> *"So we have employer surveys and interviews and discussions and try to tailor our curriculum to be sure that we're addressing the needs of our employers" [Int 20].*

This dynamic of employers expressing interests that schools then adjust to satisfy establishes a supply and demand relationship between programs and industry.

The dynamic of demand driving curricula can also come from within the university. For example, one participant described developing a writing course in response to their colleagues' demand for improved writing by their graduate students:

> *"There's been some talk about me developing another graduate level class on engineering writing because they want students to [be able to write]. A lot of people are saying, well my students can't write and I want them to be able to write better" [Int 11].*

Even an example from the opening section illustrates this same idea of the demand phenomenon driving decisions within engineering education:

> *"One respondent noted that there is a market for universities to help teach engineers business skills and provide lower cost options than business school." (Phase 1 Report, p. 17)*

The idea here is that a faculty member's time and a program's credit hour resources can be shaped by these supply and demand phenomena.

Student demands can also drive these resource allocation decisions from within the university. More specifically, their demands can affect what is being taught:

> *"one [course] was based on needs identified, and the other one students asked me to teach it" [Int 17].*

Analyzing these phenomena of supply and demand can potentially beg the question of the underlying motivations for such demands – what generated a particular preference set and what was the reason for that? In all of these examples, there is also a double-edged element in that employers, faculty members, or students could express preferences for more explicit discussions of the ethics of engineering in undergraduate programs; however, if there is no such expressed preference then programs may not take the initiative themselves to call out ethical decision-making in engineering since they are trying to allocate time and money to fulfill other demands. Characterizing this aspect of the political economy of engineering education also raises the question about the consequences of elasticities of supplies and demands. These could be fruitful areas for critical investigation in the future.

<u>Sample Questions</u>: Under what formal and informal circumstances do students feel empowered to express demands on programs to discuss engineering ethics in the curriculum?

Similarly, under what circumstances are programs more likely to accede to (or ignore) student requests? Moreover, under what conditions will students ignore the logic of supply and demand and cite other principles to justify their actions?

2. Prestige and reputation

The construction and maintenance of reputation and competition for prestige is another phenomenon relevant to the political economy of engineering education. While there are different theories with discrete operationalizations of prestige (Wegener, 1992), in an economic sense, reputation is defined as an assessment that some actors in a system make about a subset of another actor's (actor A) characteristics based on A's actions (Noe, 2012, p. 115). In higher education, Rosinger et al. (2015) have discussed the effects of what they term the "prestige economy" on interdepartmental dynamics and segmentation of high-resource departments and low-resource departments within universities. Sometimes, this transpires by universities spending money to increase their rankings (Bhattacharjee, 2011). Other times this can happen with faculty members allocating their time as part of the prestige economy (Blackmore & Kandiko, 2011). Returning to the definition of political economy, the study of social relations that determine resource allocation, struggles for prestige and reputation are within the study of political economy because those social relations determine who gains (or loses) reputation; social relations construct prestige, which departments struggle to accumulate by spending their resources.

In engineering education, the prestige and reputation phenomenon can manifest as the result of departments building their reputation for "producing high quality engineers", a reputation evaluation that companies make when considering whether to hire that department's students. As one participant stated,

> *"We always talk about how we want to prepare the best students and that way [companies] will say oh I want to go get another student from our university to hire. That's how we raise the prestige of our program." [Int 17]*

This faculty member's department wants a reputation among companies for educating engineers whom they will want to hire, and that impetus for reputation development informs decisions about how and where to allocate time and energy in the program.

At the individual actor level, this phenomenon can also transpire as the reputation that some faculty members have among their colleagues based on title:

> *"It's just that now I get the little bit of clout that comes with being on the tenure track and then after six years the advantages that come with that as well…The clout thing is important. Title matters to me." [Int 18]*

The implication here is that title is a signal of prestige, which both enables resource use and influences the faculty member's own resource allocation in an effort to maintain and advance that title.

Finally, in addition to faculty member reputation among other faculty members, faculty member reputation among students based on their teaching ability is another source of reputation and prestige:

> *"My classes, when they open up for registration, they are full by next morning. I have a good reputation. Thanks, God. I'm not bragging. I teach with my heart. I prepare. I plan." [Int 15]*

That reputation then affects students' choices for which classes and which section offerings to take.

The common theme in each of these examples is that prestige and reputation are driving behaviors among actors in the system related to how they manage their own resources and those of the system more generally. As with the supply and demand phenomena above, this competition for a positive reputation can cut both ways. On the one hand, programs fostering a reputation among companies will want to have companies know they educate ethical engineers. On the other hand, if companies do not actually value ethical decision-making among their employees then programs *could* in turn abandon that part of their curricula. Therefore, a comprehensive research agenda to characterize the political economy of engineering education should account for reputation and prestige at the individual- and group-level within the system – how it is built, the effects of that perception, the consequences of these perceptions, etc.

<u>Sample Questions</u>: How do faculty members in a department think about their program's reputation for educating engineers capable of ethical decision-making, and how does that affect their collective decision-making to allocate time in the curriculum to ethics? More generally, how does a program's reputation affect the resources that it can receive? To what degree is the Matthew effect – concisely stated as "the rich get richer" – that Merton (1968) described in science, and Perc (2014) further elaborated, also in effect in engineering education? This could potentially be relevant with engineering education departments strategically placed in colleges of engineering

rather than colleges of education. The underlying idea behind that move would be the impetus for more prestige driving decisions about curricular or even programmatic structure.

3. Outsourcing

The process of outsourcing can involve hiring an external organization to produce something which was previously produced internal to the deciding organization (Bhagwati, Panagariya, & T. N., 2004). How one delineates organizational boundaries in this context given the centrality of the internalize vs. externalize decision is pivotal in determining what constitutes outsourcing. Within engineering education, this can be the decision to have a faculty member within the department teach a course versus coordinating with another department to have one of their faculty members teach the course in question. The social relations implicated here are those between departments in a university and among committees within a department as they decide how to allocate their budgets and curriculum time. On incorporating ethics with technical content, some faculty members think it should be incorporated within the department's courses while one participant acknowledged that there are other *"faculty members in [their] department who don't believe that.* ***They think the philosophy people should teach ethics and that is it****" [Int 06]*. As a result,

> *"the philosophy department wanted support from the engineering departments to be able to pay for the instructor who was going to teach the ethics class that all of our students are required to take. So then it became a question of well I should we even have that course in our curriculum or should we incorporate ethics education into our classes and not require that individual course? And everyone decided that* ***it was way easier just to pay for that person and part for the instructor in the philosophy department to teach it than for us to worry about teaching ethics in our classes****" [Int 06].*

The same applies for statistics-based courses for engineers:

> *"it's a new course, part of a new curriculum for civil engineering, and the reason to do that was to kind of rethink how civil engineering interacts with you know making sure that students are getting education on uncertainty and data. So they did not have like a statistics-based course at the undergraduate level.* ***People would go to the math department to take it****." [Int 23].*

Departments can also outsource engineering education to centers for teaching and learning:

"I think it's the exact same issue facing engineering education research, right? Like, um, you know, the people who care about it, you know, haven't, to date, haven't really been trained in it. So they're not using rigorous methods. People who have expertise in it are young and don't have the engineering credibility, right. It's just this kind of embedded thing. ***So then they outsource it to centers for teaching and learning****, which are out of touch" [Int 18].*

Alternatively, rather than outsourcing their ethics education to another department within the university, some faculty members believe in ascribing this to the purview of the students' future employers:

"I just think they've got so much they've got to learn that, that [faculty] figure they'll just get the ethics all on the job" [Int 07].

In all of these scenarios, outsourcing decisions revolve around comparative advantage of one department or organization over another. The department collectively asks whether it is easier to outsource instruction of a topic or course rather than committing their own resources to teaching that course. The decision stems from the broader way in which resources flow within a university. While this decision follows an understandable logic, it can also have unintended consequences of disconnecting the content and segmenting the curriculum overall. Consequently, this division of labor may have observable effects on engineers' formation. The general model of producing quality-assured students ready to contribute to a competitive workforce stems from the view of universities as metaphorical factories, noted in Table 18 in the Wickendon Report's discussion of a Taylorist philosophy of education. The phenomenon is an indication of at least two things. First, applying the same models for economic development in industry to student development in education wherein human capital is simply another resource to invest in. Second, the distribution of resources in universities in connection with academic units can enable and even justify these outsourcing decisions, thereby distorting the decision-making process through an outsized consideration of cost in lieu of other considerations such as student learning.

<u>Sample Questions</u>: What are the effects of outsourcing in engineering education? Are some topics (e.g., ethics) more likely to be outsourced in the curriculum compared to others? If so, why, and what are the consequences of those outsourcing decisions? In other words, to what degree will students or faculty members employ the logic of employing someone else to complete a task that they themselves might otherwise complete, and what are their justifications for doing so? In the

eyes of faculty and administrators, where do the boundaries exist for permissible outsourcing? Do particular funding mechanisms or resource dependencies correlate with levels of outsourcing (or attitudes toward outsourcing)?

4. Program governance

Oversight and regulation of engineering education can come in several forms. One such form is actual governmental agencies such as the Department of Education. A second type of regulatory body can be private organizations like certain accreditation boards. In engineering, the Accreditation Board for Engineering and Technology (ABET) is a significant actor in that arena, at least in the United States. A third example is professional organizations, in a more indirect sense, by means of establishing and promulgating professional standards. In turn, those professional standards influence accreditation standards but they also influence licensing requirements. As a result, if an undergraduate engineering program wants to prepare its students to obtain a Professional Engineering license, then it will most likely shape its curriculum to adhere to those standards and educate their students accordingly. This creates relationships of dependence between engineering programs and accreditors, which shapes how programs allocate various resources.

4.A. Government oversight

The topic of government oversight will vary heavily among different countries. Generally speaking, government oversight here is any formal or informal input from a governmental organization to an engineering education system. In the United States, one might expect oversight from the Department of Education at the federal level or state legislatures. An example of government oversight on public universities: credit hour limits, often to reduce time and cost associated with engineering degrees. Those limits then constrain programs' curricula, causing faculty to omit certain courses and topics. To describe why their department no longer teaches an engineering economics course, one participant said:

> *"We kept getting pressure to cut units …[from] the state legislature and the Chancellor's office." [Int 01]*

Thus, pressures from political bodies can motivate decisions on how to allocate time in the curriculum. The phenomena of government regulation is therefore one dimension of the political economy of engineering education.

This is not just a phenomenon of government actions in the United States. Take the United Kingdom for a second example. In particular, Shelton (1982) discussed government oversight and academic freedom in the United Kingdom. Among other things, he observed that "the basic rationale for government involvement is a recognition of the role of engineers and engineering in national industrial and economic performance" (Shelton, 1982, p. 221). He then proceeds to expound upon this government oversight aspect of the political economy of engineering education:

> "The approach varies from country to country, but all governments have to work through the existing framework for organising, financing and managing higher education and for the registration of engineers. Governments can of course seek to change this framework to enable them to pursue their policies more effectively" (Shelton, 1982, p. 222).

In other words, governments have various mechanisms at their disposal to regulate engineering education in the name of accomplishing their objectives. Those objectives may vary, but they are commonly economic. The objectives then establish relationships among actors in engineering education, which renders this a phenomenon in the political economy of engineering education. This example from British engineering education illustrates an important point: although government can regulate engineering education in their respective jurisdictions, the details may look different depending on the objectives and economic circumstances facing those different places.

Sample Question: How do different national government oversight structures and political philosophies shape the engineering education systems of their respective countries? Are those broader national philosophies correlated with certain patterns regarding engineering ethics in undergraduate engineering programs in those countries? Work in this area would follow the example from Kabo et al. (Kabo et al., 2012) comparing the U.S., Sweden, and China or Lucena et al. (J. Lucena et al., 2008) comparing the U.S., Latin America, and Europe.

4.B. Accreditation oversight

Periodic accreditation visits from ABET play a substantial role in the oversight and regulation phenomena of the political economy of engineering education. One can hardly understate the importance of ABET in this characterization of the engineering education system. Obtaining a professional engineering license often requires graduating from an ABET-accredited engineering program (https://ncees.org/engineering/engineering-licensure/). Moreover, many job postings specifically look for graduates of accredited programs, regardless of whether those recruits have a P.E. license. The importance of graduating from an ABET-accredited program creates a substantial role for oversight and regulation by ABET. Unsurprisingly, this oversight is cited as the impetus for decision-making in engineering programs:

> *"I'm sure if ABET came along and said something like you must have an engineering ethics course otherwise you will not be accredited that would make everyone jump and make a change" [Int 02].*

Another participant states this influence differently, highlighting how oversight drives education decisions but only on a predictably intermittent basis:

> *"I feel like the education decisions only arise when they are looking at ABET assessment every 6 years, and at that point I felt like it became a begrudging okay well we have to put something in here, so what is it going to be" [Int 03].*

As numerous participants stated, in the counterfactual scenario where there were not ABET student outcomes, then there would probably not be certain courses in their respective undergraduate engineering programs:

> *"I believe that course was added in specifically to address that requirement, and absent that requirement it may not have been covered at all" [Int 06].*

In each of these cases, accreditation plays a role in the regulation phenomenon of the political economy of engineering education by informing relationships that affect how programs allocate curricular time. This is consistent with pressures reported elsewhere that occur from ABET and its ability to change the form of engineering education (Bjorklund & Colbeck, 2001).

Sample Question: How would an alternative accreditation oversight body gain leverage in a space heavily dominated by one organization? Alternatively, what are the economic pressures on ABET that partially contribute to their efforts to establish a more global presence in program accreditation? What is the process that program administrators and committees navigate to demonstrate fulfillment of accreditation outcomes related to engineering ethics? Are there patterns in how programs handle that part of their curricula that are correlated with characteristics of the department (e.g., department size, organizational structure, discipline)?

4.C. Regulatory capture

Regulatory capture is the phenomenon arising from specific groups having disproportionate influence over regulatory bodies (Bó, 2006). Such regulatory bodies include ABET for education and professional organizations for the profession more generally. If one construes internal university rules and requirements as regulations then placing department representatives on university curriculum committees can also be a form of regulatory capture. In the interviews, this arose in the form of one department member sitting on the faculty senate and course approval committee, which facilitated the approval of an engineering economics course over the objection of the economics department's and their claims of redundancy. This move was described by the participant as *"a real good coup" [Int 01]*, a description alluding to the political economic nature of that action because the university's budget structure informed the department's own resource allocation decisions and territorial relationships with other departments. Economic conditions affecting universities are shaping group and committee decisions about resources in engineering departments. These are telltale ingredients of phenomena in the political economy of engineering education.

Sample Questions: What are examples of specific efforts from actors to influence the regulation of ethics instruction by outside actors – e.g., accreditation bodies, university officials, governmental agencies, etc. – that their departments experience? Moreover, what are common themes underlying the motivations, successes, and failures of those efforts?

4.D. Regulatory burden.

Regulatory burden is the set of costs that accrue to an organization as a consequence of the organization's efforts to maintain compliance with regulations (Helm, 2006). In engineering education, one can study the overhead of compliance with ABET, for example. As one participant stated,

> *"I was actually on the ABET committee in my department to do with the outcomes and all of that, but at some point I felt that they are stressing too much paper work. That it's becoming unnecessary… you demand too much of reporting and regulations… half of your time basically is wasted on overhead" [Int 15].*

The ABET example is just one conceivable example of regulatory burden in engineering education. In a broader sense of political economy, this idea of regulatory burden is perceived as a negative phenomenon because it assumes that regulation is a burden. Under a neoliberal ideology, regulation is rarely justified, and even then only to ensure proper functioning of a market. Thus, when regulations do exist, one can easily frame them as burdensome. Of course, the regulation itself will sometimes come from the desire to create a common denominator among programs. That move translates to faculty members within a department needing to coordinate amongst each other how they will This can explain how faculty members, operating within the political economy of engineering education might see regulation with this regulatory burden perspective.

Sample Questions: Are there also associated behaviors that one observes consequent to regulatory burden in other contexts? For example, is there intentional lobbying to change the regulations or shirking from faculty members (especially in a patterned manner, such as from faculty in certain disciplines or at a certain rank) to placate regulators on behalf of the faculty members?

5. Job markets (Hiring patterns and decisions)

Hiring decisions represent a pivotal allocation of resources for an organization where group relations are implicated. They define the organization's personnel and shape future outcomes for the internal operations in manifold ways. There are at least two areas in which this general concept is relevant to engineering education. First, there are specific hiring preferences and patterns that companies exhibit. Second, there are specific hiring decisions that universities exhibit. Each of these can affect engineering education in specific, potentially unintended ways compounded by the academic capitalist competition for prestige (partially garnered through increased research funding) and reduced departmental budgets leading to academic precarity and adjunctification (Charfauros & Tierney, 1999; Courtois & O'Keefe, 2015; Reisel, 2018). In turn, these can affect how ethics is discussed in engineering programs by placing certain external expectations on programs and internal personnel with differing understandings of what engineering ethics means.

5.A. Hiring decisions by companies

This topic analyzes how the hiring decisions that companies make end up providing feedback signals to engineering departments, which in turn modify their curricula and student outcomes to align with the industry's desired traits:

"Engineering programs need to address the skills desired by the companies hiring their students" [Int 10]

As with supply and demand, the main idea here is that the relationship between engineering programs and industry can affect faculty time, curriculum time, student time, and money, allocation by influencing which courses are taught and the larger learning objectives they are designed to achieve. If companies come to a department and say "we want students who understand the nuances of ethical decision-making" then departments could predictably respond by adjusting their curricula to make ethics more visible in the departments' courses.

Sample question: How do engineering programs elicit and respond to industry feedback for prospective employee hiring preferences? Are there pattern in who (or who is not) among the potential employers surveyed such that some group's preferences have outsized influence on departmental decision-making and resource allocation? Where does engineering ethics fit into these feedback loops from industry?

5.B. Hiring decisions by departments

Decisions at the department, college, and university levels, which themselves can be the result of input signals from university administration and priorities, are another example of a specific resource allocation issue – personnel – that alter the state of engineering education. Two specific ways in which this can manifest is the hiring of adjunct faculty and the preference for research faculty in lieu of faculty with professional work experience in industry. Adjunct faculty and professors of practice may be more likely to have substantial industry experience in comparison with research-intensive tenure-track faculty. As a result, they may be less inclined to discuss particular topics or less aware of practice-specific elements such as the importance and prevalence of ethical issues throughout engineering. Consequently, this can change the state of engineering ethics education by affecting personnel who alter the content of specific courses. That cascade from hiring practices to different faculty composition to course content can culminate in developing engineers with noticeably different educational backgrounds compared with engineers who had more design-oriented or profession-oriented instruction rather than theory-based instruction.

Seeley (1999) described a similar trend in the early to mid-twentieth century as universities hired European faculty and federal grants increasingly funded research efforts. This combination cascaded into a more analytic approach to engineering and a shift away from design. As universities shift toward supplementing government-subsidized funding with research funding, they can begin to shift their hiring practices to recruit more research faculty. As several faculty members stated,

> *"We've had four candidates in and every one of them are stellar researchers, and they're expected to be productive from the day they walk in getting research contracts and publishing. That's the philosophy now. And I've noticed it in other universities when I go and talk to the faculty that have been friends, uh, I see the migration occurring all the way throughout academia for engineering" [Int 10].*

In other words, that continued trend of the competition for funding dictating department hiring, which in turn shapes program curricula, is continuing relatively unabated.

One specific example of these differences is in the positive correlation between a faculty member's years of work experience and their likelihood to incorporate ethics into their classroom (Katz & Knight, 2017) – more years of work experience as an engineer is associated with faculty members reporting more incorporation of ethics and professional responsibility in their courses on a national survey of over 1,200 faculty members. The basic premise is that every person comes with their own interests that are also shaped by incentives. This affects the interests and autonomous/individualized decision-making processes of each faculty member, which potentially translates into different content in each course offering. Of course, at the time of hire, the main consideration of the department or university may be to recruit someone capable of generating research funding. The consequences of their teaching interests may be a secondary consideration. In that picture, resource dependence drives hiring, which affects who is on the faculty, which then shapes what students learn due to the influence of personal interests in curricular decision-making.

<u>Sample question:</u> How has the political economy of engineering education shaped the hiring practices of engineering departments, and in turn shaped the ethics-related content that students learn in the undergraduate curriculum?

6. Institutional isomorphism, entrepreneurship, and inertia

By definition, when studying political economy one may focus on the generation and effects of institutions. An institution in this context is not synonymous with a university; instead, an institution is more abstract and expansive. According to the theory, an institution is any formal (e.g., rules, standards, regulations) or informal (e.g., norms, taboos, or culture) guideline that shapes behavior (North, 1991). These are colloquially deemed the "rules of the game" according to institutional theorists (Gertler, 2010). Three examples of the relevance and practicality of institutional theory for characterizing the political economy engineering education are institutional isomorphisms, institutional entrepreneurship, and institutional inertia. Together, these phenomena describe how faculty members and departments will spend their money and time either to look similar (isomorphisms) or different (entrepreneurship) as they try to maintain legitimacy or distinguish themselves to compete against other faculty members or departments.

6.A. Institutional isomorphism

Similar practices among discrete organizations are called institutional isomorphisms. In engineering education, this can manifest as one program configuring itself similarly to another, possibly more prestigious program, to gain legitimacy or resources (DiMaggio & Powell, 1983). These isomorphisms further divide into coercive, mimetic, and normative. Departments may adopt a coercive isomorphism strategy when they depend upon other organizations, e.g., NSF or state legislatures, for resources and do not want to try suspicion upon themselves by standing out in a dubious way. In the interviews, this often arose from coercive isomorphisms of course content and structure. As one participant stated,

> *"They've been trying to combine some like advising and professional development stuff with some ethics-ish stuff, but I'm not sure if they're doing a particularly good job with it. I think unfortunately they compare themselves to peer institutions and I don't think anyone does a great job" [Int 19].*

This highlights the unfortunate effects of holding everyone to a low bar.

In addition to coercive isomorphisms, mimetic isomorphisms a popular strategy in the face of uncertainty from changing educational landscapes, industry demands, accreditation standards, leadership, etc. – can exist. For example, one participant described their department's senior capstone course as another mimetic isomorphism (at least in effect, if not intent):

> *"Our senior design here and everywhere I know at every university…it's almost universally the same." [Int 17]*

That institutional isomorphism may arise because there genuinely is no other way to run a senior design course. Alternatively, it could be the consequence of this mimetic isomorphism created by environmental uncertainties inherent in the political economy of engineering education (which itself is a product of broader economic landscapes in which paradigms like creative destruction (Schumpeter, 1942, p. 82) prevail). These ideas relate to the political economy of engineering education because they illustrate the effects of operating in a system of unpredictable flux. As a result of needing to meet demands from industry, balance resources, and generally stay afloat, departments and faculty members may turn to mimetic or normative isomorphisms as harbors from the storm to ensure survival. This could help explain similarities that one observes among different departments in how they teach ethics.

Sample Question: How have institutional isomorphisms affected engineering education program innovation, particularly related to engineering ethics, over the past 30 years? For example, in an editorial in *Science*, Morgan (1990) called for more programmatic diversity enabled by loosened accreditation standards. The claim: stringent bean-counting practices in accreditation stymie innovative practices in engineering education. The corollary is that engineering programs can start to look the same – isomorphic. In other words, from the perspective of institutional theory, accreditation might increase coercive isomorphisms. Is Morgan correct that accreditation is the mechanism of action for observed isomorphisms in engineering programs, or are there some other causes? This is just one instance of several potential dimensions in the political economy of engineering education that generate these institutional isomorphisms.

6.B. Institutional inertia and entrepreneurship

The creation of new institutions within organizational settings is labelled institutional entrepreneurship (Pacheco, York, Dean, & Sarasvathy, 2010). In engineering programs this may transpire in the form of a department initiating particular practices or traditions, such as requiring graduating seniors to join the Order of the Engineer. As one faculty member stated,

> *"there's a clause that allows Canadians to restart it if they have an engineering degree. Enough of us were here that we restarted it and we also pushed this in the senior classes like we would go there and send announcements that there is this obligation side to what you do and we conducted the ceremonies. And we also convinced our faculty colleagues to also get the ring and think about this a bit more" [Int 02].*

Another example might be the creation of an effort to incorporate a program in social responsibility:

"we had one really young philosophy professor who really got interested in social responsibility and actually he was the major person creating an actual degree that we offer in this field of social responsibility" [Int 01].

If the inspiration to create such a program originated from seeing other programs, then such an initiative may also be an institutional isomorphism. On the other hand, when these decisions are inspired without a desire to emulate other programs then they more likely represent institutional entrepreneurship.

For studying the political economy of engineering education, one may ask about the precursors or antecedent conditions that give rise to institutional entrepreneurship in engineering ethics education. This is particularly germane to the efforts of reformers in engineering education who may want to encourage this institutional entrepreneurship and promulgate best practices related to developing ethical engineers on a large scale.

Institutional inertia is a counterpart of institutional entrepreneurship – they can be viewed as two sides of the same coin. As the name suggests, institutional inertia is the obstinate persistence of an institution, especially in the face of efforts to change it. Examples can include intractability of curricula or pedagogical practices to updates, in part due to a status quo bias. One participant observed the role of institutional inertia in a curriculum,

"I think a lot of it just has to do with inertia. This is what is in the program and that just stays in the program until somebody makes an argument that it shouldn't be in there and why we should add something." [Int 06]

Identifying institutional inertias is one task. A related task lies in identifying the reasons for institutional inertia. A separate participant observed,

"I think people are stretched so thin and we are in an environment where it seems to be working, so why spend a lot of extra effort developing something that is already working? So I think mostly has to do with apathy and lack of time rather than anything malicious." [Int 20]

As this quote suggests, institutional inertias may be a phenomenon in the political economy of engineering ethics education not through intentional action but rather through a crowding out of faculty members' time and energy in the push for more funding, more publications, and more students to the detriment of spending time thinking about ways to incorporate more ethics. Due to other demands placed on that time and energy, faculty members lack the bandwidth to advocate and sustain institutional changes, which ultimately generates this institutional inertia.

Sample Question: What are the political economic precursors that facilitate institutional entrepreneurship related to engineering ethics in engineering programs? As with the institutional isomorphism question, does the political economy of engineering education constrain (or incentivize) certain kinds of institutional entrepreneurship – e.g., starting a program on innovation, recruiting donors to fund a maker space, or adopting research-based practices for teaching an engineering ethics course like thermodynamics? Lessons from the trailblazers in chapter two also apply here because they themselves were institutional entrepreneurs under this framing.

Limitations

Reification

By naming some of these phenomena one might invite the problem of confusing the model for the actual instances of interaction in the world. Reification is the process of making an abstract concept or idea more concrete. An example could be the act of turning "prestige" into a more tangible entity in the world rather than an agreed upon or recognized concept. The purpose of this paper is not to reify the aforementioned phenomena but rather to provide a model for thinking about social relations in engineering education and how those affect time, money, space, and human resource allocation. As Box (1987) reminds us, "all models are wrong, but some are useful". The model here is the set of concepts from prototypical study of political economy. The utility is in understanding constraints shaping engineers' formation. To guard against reification, we should maintain a level of reflexivity and apply a critical perspective to the work, continuously re-analyzing these ideas and the work they are doing for us.

Normalization

Discussing engineering education in these terms might also imply a normative stance that the underlying extant relations described by this framework are suitable. No such implication is intended. Indeed, the spirit of this project is one of questioning the merits of those existing patterns. The critical task is in the same vein as the saying attributed to Bertrand Russell that "in all affairs it's a healthy thing now and then to hang a question mark on the things you have long taken for granted"; thus, the project questions the normative practices in place, and the narratives we construct around them as justification.

Category Error

Understandably, some may balk at the notion of taking an entire framework from one discipline and applying it to engineering education. Such reservations may assert that this is a category error. While arguably true, in a pragmatic sense, if labeling these problems in such borrowed vernacular offers useful tools for thinking and improving current conditions in the system then the framework's utility could outweigh downsides. Essentially, these are tools for thinking about problems. Much in the same way that some may fabricate a bifurcated socio-technical dualism in order to compartmentalize (and eventually downgrade) the social elements of engineering from the technical aspects, insisting that some concepts are ill-suited a priori for engineering and engineering education research is a premature conclusion. Claims of inapplicability would require justification just as the preceding claims of applicability require their own justification. Is it not better to judge the claims based on their merits rather than preconceived synthetic disciplinary barriers?

Claims of applicability notwithstanding, this paper is not intended to politicize engineering education to an unwarranted level; however, ignoring the effects of social, political, and economic factors on engineering education does not nullify these factors' effects. They still exist whether or not participants in the system like it. Refusing to acknowledge these dynamics – whether it is promotion and tenure for engineering education research, interdepartmental curricular disputes for credit hours, student choices creating a demand for change, or industry representatives placing pressures on departments to teach particular skills – does not nullify their existence.

Conclusion

I have presented a set of conceptual tools to elucidate the social relationships that inform how time, money, space, and human resources are spent in engineering education. These tools deepen analyses of change in engineering ethics education by making visible the larger political economic forces affecting higher education in general, and engineering education in particular. There clearly are relationships among the different actors, organizations, and institutions within the system. Those relationships establish individual and organizational priorities, preferences, and behaviors for how we allocate time, money, and human resources toward ethics instruction in universities, colleges, departments, courses, and classrooms. This is a picture in which decision-making about resources is political, depending on the confluence of people, organizations, and environments to determine who gets what, how, and when – the very (pithy) definition of politics (Lasswell, 1936).

Anyone participating in the engineering education system in some way will most likely recognize the confluence of social, political, and economic factors that shape decision-making processes within the system. Sometimes those factors engender specific phenomena that have been studied in other contexts. By learning lessons from those prior studies, engineering educators, researchers, administrators, and professionals can refine how they view the engineering education system. In turn, that refinement might enable several outcomes: increased awareness of surrounding processes, improved decision-making, and new avenues for research in order to more clearly understand the state of U.S. engineering ethics education. Being mindful of the political economy of governance, labor, and relationships within the system, we can advance our understandings of change in engineering ethics education, ultimately improving processes and outcomes in practice.

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CHAPTER 5: CONCLUSIONS AND IMPLICATIONS FOR THE STATE OF U.S. ENGINEERING ETHICS EDUCATION

Preface

In this chapter I return to the central topic of this dissertation – understanding the state of U.S. engineering ethics education. I review the main conclusions from my three approaches to addressing the topic and discuss their implications with respect to each other. My goal is to identify common themes among the chapters, highlight how one chapter helps address the weaknesses of a different chapter, and reach larger conclusions best supported only when the three chapters work in unison. I end by suggesting avenues for future work and practices in the areas of engineering ethics education, change management, and the political economy of engineering education.

Returning to the Central Question (Findings and Contributions)

This dissertation started with a simple observation: engineering ethics education is important, *but* there tends to be significant room for improvement in the quantity and quality of how engineering students learn ethics in programs across the United States. That observation then led to the central inquiry into the nature and causes of the state of U.S. engineering ethics education. Studying faculty members initially seemed like a natural place to start understanding this disconnect – they control large portions of content and pedagogy in classrooms. However, looking at faculty members in isolation would leave open questions about historical contingencies and structural influences. Therefore, to address this inquiry, I used three complementary approaches, shown in Figure 15.

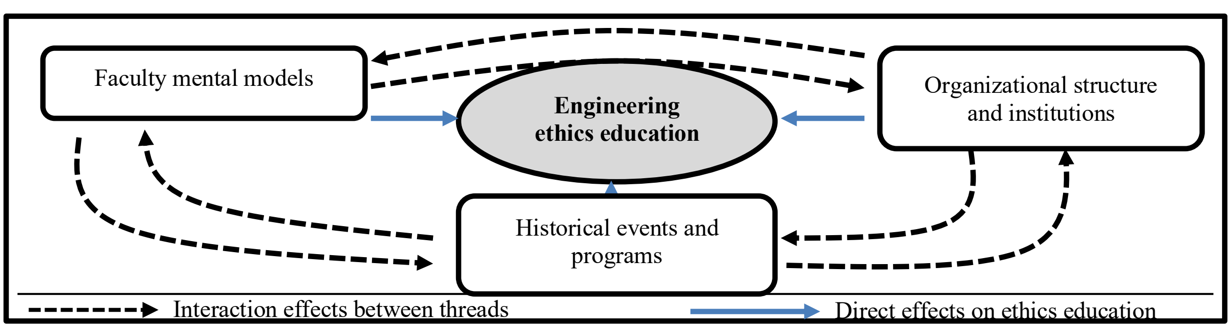

Figure 15. Three projects to study engineering ethics education.

First, to answer research question one ((a) How has U.S. engineering ethics education changed since 1970? (b) What are the common themes in the stories of engineering ethics education trailblazers?, I used an historical approach to identify changes and themes in the stories of change as instigated, witnessed, and experienced by 12 trailblazers in the field of engineering ethics and engineering ethics education over the past 45 years. From this study, I identified three categories of common themes across the stories:

1. Interpersonal Relationships
2. Institutions and Organizations
3. Resources

In the interpersonal category, training and mentoring, networks, and allies were all dominant themes for making changes in engineering ethics education. The trailblazers often worked in collaborations and communities to learn from each other and help shape future generations of engineers and scholars. Of the institutions and organizations, mechanisms for promulgating ideas (e.g., journals, textbooks, scholarly books, newsletters), organizations outside universities (e.g., professional societies, scholarly associations), and the influence of other professions were important themes. The institutions and organizations provided the scaffolding and environments in which the trailblazers could operate more effectively. Finally, the pressures, rewards and incentives all constituted the third thematic category, catalyzing, enabling, and sometimes hindering the trailblazers' work. Together, these themes paint a picture in which individual trailblazers brought their own personal histories and experiences with them as they worked together in groups and networks to advance conversations and practices around engineering ethics education. Their efforts created pedagogical materials, prevalent ideas, publication outlets, meetings, and foundations that not only contributed to the current state of U.S. engineering ethics education but also the launching point for future generations to build upon and continue developing that state.

Next, to answer research question two (what are the mental models that engineering faculty members have of engineering ethics education?) and continue understanding the state of ethics education, I studied the mental models of the people who control curricular and pedagogical decisions (i.e., faculty members). My work revealed ten areas of a faculty member's mental model that relate to engineering ethics education. Each area, in turn, has different types of models that a faculty member may possess. The ten identified areas are:

1. Definitions of engineering ethics
2. Contents of engineering ethics
3. Goals of ethics instruction
4. Where students learn engineering ethics
5. When students learn engineering ethics
6. When engineering ethics is taught
7. Who makes decisions about engineering ethics
8. Who teaches engineering ethics
9. How engineering ethics is taught
10. How students learn engineering ethics

These ten areas provide a typology for analyzing the state of engineering ethics education and places where one can expect to find variation from department to department. Likewise, variation within those areas, i.e., specific models, further help understanding the state of engineering ethics education. The lonely island model, part of area five (when students learn engineering ethics), entails a curricular state of existence-but-isolation for engineering ethics in an engineering program. The same pattern of mental models reflecting and shaping the local state of engineering ethics education applies to all the mental models in all of the other areas.

In total, the areas and models help map the space of possibilities in the overall ethics education state space. For any researcher or administrator interested in how future engineers learn engineering ethics, these areas and models are paramount to consider. While many of the areas have been researched and discussed in the literature individually, my contribution here comes from delineating a more complete spectrum of the areas and the respective models within those areas. I also have provided another use of the mental models methodology – a pragmatic approach to studying learning – in engineering education research…

Finally, to answer research question three (How might the political economy of engineering education affect decision-making processes concerning engineering ethics education?), I outlined a theory of how the political economy of engineering education could be influencing curricular and pedagogical decisions in engineering departments. To do this, I took concepts and phenomena from the traditional study of political economy and identified areas in engineering departments where those phenomena could arise. My contribution here was to propose a novel way of thinking about and studying interactions in the engineering education ecosystem that affect the development of future engineers. Doing this extended the academic plan model by directly incorporating specific phenomena that the extant model either omits or underspecifies. I supplemented the outlined theoretical phenomena with re-analyzed data from the mental models interviews in order to provide a proof of concept and relevance for these six phenomena. The list includes:

1. Market-like behavior
2. Competition for prestige and reputation
3. Outsourcing
4. Program governance
5. Job markets and hiring
6. Institutional isomorphism, entrepreneurship, and inertia

From these phenomena, one can see how the political economy of education might affect the state of engineering ethics education. Oversight from accreditation bodies like ABET, which also factored into several mental models areas (e.g., area three of faculty members' mental models "why teach ethics") can drive curricular decisions to incorporate some aspect of engineering ethics. Outsourcing, which factored into areas seven (who makes decisions about engineering ethics education) and eight (who teaches engineering ethics education), can drive content and pedagogical decisions since faculty trained in different disciplines may approach the topic differently. This was one of the ideas behind the National Project on Philosophy and Engineering Ethics that paired engineers and philosophers together. Lobbying and voting behavior similarly factors into area seven since curriculum committees are positioned to promote or relegate engineering ethics in the curriculum and faculty members may lobby the committee to vote in specific directions. The bottom line in these examples: these phenomena that are part of the political economy of engineering education help shape the mental models of engineering faculty members; those faculty members then proceed to make decisions that affect the state of engineering ethics education.

Connecting the pieces, we see that all three projects speak to each other in a complementary fashion. They give a more complete understanding of factors that affect the state of U.S. engineering ethics education. Specifically, if we want to understand the state of engineering ethics education in the United States, then we have to account for the political economy of engineering education – how resource scarcities that programs encounter shape their decisions to allocate time, money, space, and human resources; how relationships with industry establish co-dependencies that inform what and how students learn; how the competition for prestige and reputation concentrates efforts to innovate in some areas of the curriculum and not others; how university and department budgets can determine who is teaching engineering ethics; how a department's impetus to grow its faculty might counterproductively lead to diffused responsibility to teach ethics; or how the fight for research funding leads to hiring more faculty with research experience in lieu of industry experience, which in turn can affect what and how those faculty members teach. The trailblazers and faculty members in the mental models study all discussed these phenomena, which I anticipated when designing the dissertation. They provided concrete examples of the social relations in the political economy of engineering education and how the individual faculty members, history, and structure come together to affect engineering ethics education.

Faculty members make decisions based on their mental models. Structural factors shape the broader environment and institutions in which those faculty members operate. Those structures and institutions change over time, leading to the current state of engineering ethics education. Having all three pieces has provided a more complete answer to the goal in chapter one of understanding the state of U.S. engineering ethics education. While the confluence of these phenomena may not completely explain the state of engineering ethics education, it helps elucidate significant contributing factors.

Recommendations and Future Work

The work that I have presented in this dissertation should appeal to researchers, administrators, and educators – both within the engineering ethics education community and beyond. For those people whose work concerns engineering ethics, there are obvious connections; yet, even if someone does not explicitly work in the engineering ethics space and but still works in an organizations or is trying to change institutions, these themes of historical change management and the political economy of a large institution like engineering education provide general lessons will pertain to their work. To illustrate the relevance to various audiences, I now recommend new avenues for future work in research and practice.

Future research

This work raises myriad questions. Some of these questions are by design. In chapter four, I explicitly stated questions when exploring each of the phenomena and how one might study them under the rubric of the political economy of engineering education. This future research will entail delineating which parts of the theories and phenomena that I outlined are empirically observable and relevant to the engineering education community. From those observations, researchers can then more deliberately measure the effects of those phenomena on behaviors and attitudes within engineering departments and how that translates into engineering practices. This line of work would also extend the academic plan model by incorporating political economy more explicitly into the framework.

Other questions were anticipated. For example, the mental models work in chapter three was predicated on characterizing the space of mental models. That characterization enables subsequent questions like, how prevalent are certain mental models among a larger sample of engineering faculty? Which factors (e.g., demographic, organizational, and institutional factors) correlate with different mental models? To address the questions, the next step for this work could be a national survey based on the mental models to study correlations between some of the models and an array of factors ranging from the structural (e.g., discipline, university type) to personal (e.g., work experience, teaching experience, ethics education exposure).

Yet a third line of questions comes from unexpected findings in the data. One such finding was the gap between normative and descriptive responsibilities that participants reported. In particular, when asked about who is and who should be responsible for students learning about engineering ethics, there were differences. This raises the question, how do faculty members' externally and internally imposed responsibilities affect their pedagogical decisions? Additional questions about the mental models also arose from this work. For example, how amenable are these mental models to changes, and are there better (or worse) strategies for changing them?

A fourth line of research can take these findings and make comparisons beyond the dissertation's geographical and topical scopes. For example, one comparison can extend beyond the United States to look at the state of engineering ethics education in other countries, looking at mental models of faculty in *those* settings and their own trailblazers' stories. Alternatively, one could stay within the United States and compare the trailblazers' stories in engineering ethics education with those of trailblazers that Atman (http://bit.ly/engredupioneers) compiled related to change in engineering education. The goal here would be to identify broader themes and see if there are ideas that are either unique to engineering ethics education or maybe applicable to a broader spectrum of topics in engineering education (or beyond).

Future practice

Along with recommendations for future research, the results in this dissertation provide a foundation for recommendations in future engineering education practice. I start with recommendations for administrators. Next, I recommend actions for faculty members. Finally, I make suggestions for engineers and a parting message for the broader engineering education community.

For administrators, I recommend several items. First, I suggest focusing attention on how are we helping develop future generations of engineering ethics educators. In particular, based on the results from all three projects, I recommend: sponsoring more graduate student training programs; incentivizing innovative activities in the classroom; encouraging collaborative, interdisciplinary projects, especially those that extend across multiple universities – Camp AfterNext, hosted at Purdue University in 2018, is a recent example of this; and establishing ways for faculty members to develop a career around engineering ethics and engineering ethics education rather than it being a secondary or supplemental activity. As part of this drive to foster interdisciplinary projects, I think the community should welcome people from a panoply of disciplines rather than starting to impose artificial boundaries. This was part of the trailblazers' stories in discussing the influence from other professions. Finally, departments, colleges, and provosts should consider the implications of their hiring practices, since those personnel decisions can have direct and indirect effects on the state of ethics education.

For faculty members, I recommend starting with local change. Shifting the state of engineering ethics education can start in their own classrooms. Faculty members can consider something as simple micro-insertions (Davis, 2006), short lessons in ethics, which can come from seeking out collaborations with colleagues across campus in philosophy. As the trailblazers project illustrated, many fruitful relationships have come from engineering and philosophy faculty members working together.

Additionally, for those looking to encourage grassroots changes to their department's curriculum, I suggest considering their colleagues' mental models – and variation among the different areas of those models. These areas and models can lead to different normative beliefs and practices, so it is also important to try discerning which are the normative models and which are the descriptive models. The different categories of models may also have different root causes, and strategies to change one may be ineffective for changing the other. For example, someone who has an area four (where students learn) normative mental model that students should learn engineering ethics on the job after they graduate may need to hear why undergraduate studies are a more developmentally advantageous time to be learning about ethics (Rest & Narváez, 1994).

For engineers, I have two recommendations. First, maintain relationships and open channels of communications with engineering departments in order to express the importance of engineering ethics for students. These feedback loops from industry clearly help provide input for subsequent iterations and changes to the engineering curriculum in departments. That information also helps to inform faculty members' mental models. Maintaining connections with engineering departments also allows for collaborations between people operating in academia and those operating outside of academia. Second, I suggest that engineers be overt and intentional in their discussions of engineering ethics anytime they are mentoring junior engineers and students. While formal education venues are *a* way for engineers to learn about engineering ethics, they are not the *only* way. As some of the models for when and where students learn engineering ethics (and who is teaching engineering ethics) highlight, this kind of education is not isolated to engineering classrooms.

Finally, for *everyone* involved (administrator, engineer, faculty member, student, researcher, etc.), I recommend the attitude of the shoe salesperson who, upon arriving in a town where nobody wears shoes thinks, "what a great opportunity – they don't wear shoes yet" rather than "this is a lost cause – they don't wear shoes here". I suggest that we have a similar situation here with engineering ethics and engineering departments. We can think it's a dead end or we can take the lessons from this dissertation – the strategies in the trailblazers' stories, the mental models of the faculty members as a map of areas to address, and the phenomena in political economy as flagged obstacles (or helpers) – and embrace the opportunity. The state of engineering ethics education, though currently suboptimal, is also clearly malleable. There are great opportunities to continue advocating for change. While indeed there is still ample room for improvement, there have already been plenty of changes over the past 45 years. By considering the confluence of individual faculty agency and the political economy of engineering education, more positive changes to the state of engineering ethics education may lie ahead. The need for such change certainly is not going away.

References

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APPENDIX A. SELECT EVENTS IN DEVELOPMENT OF ENGINEERING ETHICS EDUCATION

Code	Event type
A	Accident
S	Scholarship
P	Profession/professional society
W	Workshop
Ed	Education
CODE	Ethics Codes
Pol	Politics

Date	Event	Code
1818	Institute of Civil Engineers formed in England	P
1852	ASCE formed	P
1871	AIME formed	p
1880	ASME formed	P
1906	AIEE President Schuyler Wheeler calls for code of ethics	CODE
1912	AIEE creates code of ethics	CODE
1914	ASCE adopts ethical guidelines for engineers	P
1918	Boston molasses flood	A
1921	Teapot Dome	A
1922	Engineering Issue in Annals of Political and Social Sciences	P
1934	NSPE Formed	P
1935	Reference to a proposed Society Code of Ethics in May issue of The American Engineer	CODE
1940	Tacoma Narrows Bridge collapse	A
1947	Canons of Ethics for Engineers of the Engineers' Council for Professional Development suggesting public welfare	CODE

1954	NSPE starts Board of Ethical Review	P
1954	NSPE adopt Engineer's Creed	CODE
1955	JEE article on the four ethical issues	S
1957	Launch of Sputnik	Pol
1963	AIE and IRE merge to form IEEE	P
1964	NSPE adopts code of ethics in its current general form	CODE
1965	NSPE Survey	P
1968	Goodrich A7-D brake failure case	A
1969-1970	Recession	Pol
1970	EPA founded	Pol
1971	OSHA founded	Pol
1972	OTA formed	Pol
1971	Frontiers in Education formed by IEEE Education Group	S
1972	EVIST formed	S
1972	ACM adopts code of conduct	CODE
1972-73	Ford Pinto case	A
1972-73	BART Case	A
1972	Tuskegee airmen	A
1973-74	Watergate	Pol
1973-1975	Recession	Pol
1974	DC-10 Turkish airlines	A
1974	What's the remedy for discrimination?	CODE
1974	NCEE adopts Rules of Professional Conduct for Professional Engineers	P
1974-1976	Baum is Director of NSF's Program on Ethics and Value Issues in Science in Technology	S
1975	AAAS Workshop: Interdisciplinary Workshop on the Interrelationships Between Science and Technology, and Ethics and Values	W
1975	Google ngrams engineering ethics tipping point	S
1975	IEEE members push for ethics committee	P
1976	Love Canal gains publicity	A
1976	Weil starts teaching engineering ethics class at IIT	Ed
1976	Center for the Study of Ethics in the Professions established at IIT	S

1977	*America By Design* by David Noble Published	S
1977	IEEE-USA Activities Board's Task Force develops ethics support and disciplinary procedures for members	P
1978	IEEE ethics committee established	P
1978	IEEE MCC creates Barus Award for Outstanding Service in the Public Interest; BART engineers are first recipients	P
1978	*Ethical Problems in Engineering* by Baum and Flores	S
1979	Virginia Mary Edgerton receives second Barus Award	P
1979	Three Mile Island Accident	A
1979	AAAS Workshop: Professional Ethics in Science and Engineering Project	W
1979	Workshops on ethical issues in engineering	W
1979-1980	Recession	Pol
1980	ECPD changes to ABET	Ed
1981	Hyatt Regency walkway collapse	A
1981-1982	Recession	Pol
1982	*Controlling Technology: Ethics and the Responsible Engineer*, 1st ed. Published	S
1983	*Ethics in Engineering* by Martin and Schinzinger published	S
1983	*Engineering Professionalism and Ethics* published	S
1983	Strategic Defense Initiative proposed	Pol
1984	NCEE updates *Model Rules of Professional Conduct*	P
1984	Bhopal pesticide plant disaster	A
1986	Chernobyl nuclear accident	A
1986	Challenger explosion	A
1986	*Revolt of the Engineers* Published	S
1988	Mechanical engineering profs at IIT approach Weil et al. looking to integrate ethics across the curriculum	Ed
1988	Agenda workshop for Ethics and Values Studies Program from NSF	W
1989	Exxon Valdez oil spill	A
1989-1991	Recession	Pol
1990	Weil replaces Hollander for 1 year at Ethics and Values in Society NSF program	S
1991	*Ethical Issues in Engineering* by Deborah Johnson published	S
1991	IIT workshops: Ethics across the curriculum	W

1992	First annual APPE conference	P
1994	NSF Workshops for High School Science Teachers: Ethics in the Classroom	W
1994	*Controlling Technology: Ethics and the Responsible Engineer*, 2nd ed. Published	S
1995	IEEE establishes Ethics Committee, requires members to adhere to code of ethics	P
1995	*Science and Engineering Ethics* journal begins publication	S
1997	IEEE Computer Society establishes code	CODE
1999	ASEE issues statement on engineering ethics education	Ed
2000	ABET implements EC2000	Ed
2001	Recession	Pol
2001	Rock Ethics Institute formed	S
2001	National Institute for Engineering Ethics housed at Texas Tech	S
2001	IEEE ethics and member conduct committees combine to form IEEE Ethics and Member Conduct Committee	P
2001	"The NSPE Board approved the following change to the Code of Ethics: Deletion of Section III.1.e. "Engineers shall not actively participate in strikes, picket lines, or other collective coercive action.""	CODE
2001	Versailles wedding hall collapse	A
2003	Columbia shuttle explosion	A
2005	Levees failure in New Orleans	A
2006	"Engineers shall strive to adhere to the principles of sustainable development1 in order to protect the environment for future generation.""	CODE
2007	Prindle Ethics Institute established at DePauw	S
2007	Center for Engineering Ethics and Society formed	S
2007-2009	Recession	Pol
2010	Deepwater Horizon oil spill	A
2011	SEE report on APPE panel	S
2015	*Engineering Ethics for a Globalized World* published by Murphy et al.	S
2015	Volkswagen emissions cheat device scandal	A
2016	IEEE Global Initiative for Ethical Considerations in Artificial Intelligence and Autonomous Systems	P
2017	Ethics training mandatory for P.E. and P.S.s	P
2017	ABET changes from 3 a-k to 1-7	Ed
2017	*Global Engineering Ethics* published by Luegenbiehl and Clancy	S

APPENDIX B. MENTAL MODELS INTERVIEW PROTOCOL

<u>Basic Prompts</u>:
Anything else?
Can you tell me more?
Can you explain why?
Can you elaborate?
Just tell me what comes to mind...

Introduction
This project is about trying to understand the role of faculty members in engineering ethics education. With that in mind, I'd like you to tell me about engineering ethics education.

The interview questions are divided into two sections. The first section asks more basic questions while the second sections contains more personal questions, specifically about some of your personal experiences. At the end of each section there will also be a prompt inviting you to add anything else that may not have come up in the questions. Please keep in mind that there are not necessarily any correct or incorrect answers in this interview. If anything is unclear in the questions, please do not hesitate to ask for clarification. Also, if at any point you want to end the interview for any reason please just say so.

Do you have any questions before we begin?
__|__ Just to get started, can you tell me a little bit about your roles and responsibilities as a faculty member?
__|__ In a typical year, what do you teach? [Follow up with ethics, if applicable]
__|__ What were your individual experiences with engineering ethics education as a student?

Individual (Background) Questions
This is the second section of questions, which will be shorter than the first section. Also, these questions will be more individual than the preceding ones.
__|__ What are your individual experiences with engineering ethics education as a faculty member?
__|__ What does your department/college/university require regarding ethics education?
__|__ Does anyone outside the department engage in developing the ethics curriculum?
__|__ What are the elements in the course(s) that you teach that address engineering ethics, if any?
__|__ Why do you want to (or not want to) teach engineering ethics?
__|__ How often do you speak with other faculty members (or students? Or anyone else?) about engineering ethics?
What else has influenced your thinking about engineering ethics?
__|__ Have you worked as a practicing engineer? If so, for how long?

__| This is the end of the first section. Do you have any concluding thoughts or comments on engineering ethics education at this point? Perhaps things you just remembered or didn't have an opportunity to mention?

[What]

Now I'm going to ask a series of definitional questions…
__|__ How would you define engineering ethics? [What's the variability?]
__|__ How would you define [describe] engineering ethics education?
__|__ How broadly do you think these definitions are shared?
__|__ What would constitute the content of an engineering ethics course? definitions entail in engineering (ethics?) courses?
__|__ Can you tell me more about the content of engineering ethics courses.
__|__ Can you please describe some of the factors that affect this content of engineering ethics courses? [And how do these factors affect the content of these courses?]

[WHO]

Next, I am going to ask a few questions about the actors involved in engineering ethics education…
__|__ Within or outside of your department, who is involved in making decisions about engineering ethics education?
__|__ Who is involved in teaching engineering ethics?
__|__ Who is responsible for students learning about engineering ethics?
__|__ Who is affected by engineering ethics education?

[WHY]

These next questions will be about the motivation and purposes of engineering ethics education.
__|__ Should students learn engineering ethics? [Why?]
__|__ Can you describe some of the goals at the course (and program) level of engineering ethics education, i.e., why is engineering ethics taught?
__|__ How does teaching ethics meet these goals? [OR how are these goals met?]
__|__ What do you think the goals *should* be?
__|__ Why do you think faculty members would teach engineering ethics?
__|__ Why do you think faculty members would not teach engineering ethics?
__|__ Why are some faculty members more motivated to get involved in teaching engineering ethics?
__|__ Why are some faculty members selected to teach engineering ethics?
__|__ [Why might a faculty member want to teach engineering ethics?]

[WHEN/WHERE]

Now I will ask a few questions about when/where engineering ethics education occurs…
__|__ When is engineering ethics typically taught (in programs you're familiar with)? Why do you think that is the case?
__|__ When *should* engineering ethics be taught? Why?
__|__ Where do students learn engineering ethics? This does not necessarily have to be specific to the university.

[HOW]

Now I'm going to ask some questions about process.

__|__ Can you tell me about what happens in the typical engineering ethics class or course?
__|__ Can you describe the ways that faculty members teach engineering ethics.
__|__ Describe some of the ways that faculty members can teach engineering ethics, if you think there is a difference between current practices and possible practices. ["I don't know" is an acceptable answer.]
__|__ Describe how engineering ethics *should* be taught.
__|__ Describe how students learn engineering ethics in classrooms.
__|__ Describe how students learn engineering ethics in general.
[Outside of the classroom, how…]
[How receptive are students...for those who teach ethics…]
__|__ Can you describe some of the factors that affect how engineering ethics is taught? [use 'department', 'university-level', and 'external' as follow-up questions] And can you discuss the types of effects that these factors might have?

__| This is the end of the second section. Do you have any concluding thoughts or comments on engineering ethics education at this point? Perhaps things you just remembered or didn't have an opportunity to mention?

APPENDIX C. ADDITIONAL PHENOMENA IN POLITICAL ECONOMY OF ENGINEERING EDUCATION

In this supplemental information section, I present additional phenomena that exhibit aspects of the political economy of engineering education. Following the pattern in chapter four, in Table 20 I present the phenomena, their brief descriptions, relevant relationship that the phenomena could affect, and implicated resources that the relationships affect as a result. I then expound upon each of these phenomena with a more detailed description, sample quotes, and questions to further explore this phenomenon in the political economy of engineering education.

Table 20. Additional phenomena from the political economy of engineering education.

Phenomenon	Description of Phenomenon	Relevant Social Relations*	Implicated Resource(s)
7. Lobbying and voting	Faculty members advocate in front of other faculty members or a committee in favor of a particular action	Stu-Dep; Stu-Fac; Stu-Uni; Dep-Fac	Fac time; Curriculum time; Stu time; Money
8. Market failures	Market-like behavior establishes relationships with unintended consequences	Dep-Dep; Pub-Dep; FacMem-FacMem	Fac time; FacMem research budget; Dep budget
9. Collective action	The group (typically of faculty members) must coordinate action in order to achieve a goal	Dep-Dep; FacMem-FacMem	Fac time; Dep budget
10. Tragedy of the commons	Actors in system exhaust a common pool resource because nobody has incentive to curtail their own use of the resource	FacMem-Stu; Dep-Ste; FacMem-FacMem	Fac time; Curriculum time; Stu time
Abbreviations: Dep-department; Fac-faculty; Uni-university; FacMem-faculty member; Stu-student; Pub-public; Eval-accreditation evaluator; Comm-committee; Ind-industry * Relations between actors/groups/organizations in the system are depicted with a hyphen. For example, a relationship between industry and a department appears as “Ind-Dep”			

7. Lobbying and voting. When faculty members want to advocate for changes to program or course curricula, they may resort to lobbying other faculty members to provide their support in committee meetings. The ultimate goal of this behavior is to affect the program configuration in a specific way. For example, faculty members allocate time and energy to convincing other faculty members and/or committees (the social relations) to allocate curricular time (the resource) to a specific theme or course, like engineering ethics. A simple example comes from Potters and van Winden (1992) suggesting that the characteristics of the individual or group lobbying have a strong influence over the policymaker's eventual behavior, especially under conditions of asymmetric information between actors. In the engineering education setting, this could manifest as faculty members who possess more clout, authority, or information in the department being more successful in their potential efforts to change policies within the department. Likewise, this could arise from college administrators lobbying accreditation bodies in a manner approaching the aforementioned regulatory capture phenomenon.

Sample Question: What are some of the factors that modulate the likelihood of faculty members lobbying committees for (or against) proposed changes? In particular, which incentives established under the political economy of engineering education are influencing this voting and lobbying behavior? For example, are there considerations that come from pressure to write grant proposals or publish journal articles that constrain a faculty member's time for learning new pedagogical techniques and therefore motivate them to vote against a curricular change? Similarly, might foundation partners funding entire departments encourage individuals to lobby for particular ideas, such as engineering entrepreneurship programs?

8. Market failures. There are several known, studied issues in the functioning of markets and where they are susceptible to failure. In this case, failure could represent an inefficient allocation of resources. This section will concentrate primarily on the phenomena associated with market failures insofar as they pertain to the political economy of engineering education rather than the engineering profession.

Nominally, some of the characterized areas of markets failures include noncompetitive markets, public goods, the presence of externalities, time-inconsistent preferences, information asymmetries, and principal agent problems. The following pages will consider each of these in turn. It is important to note that this is a theoretical piece intended to identify areas of potential interest for researchers, educators, and policy-makers. To the extent that each of those groups considers systemic issues in engineering education, they might benefit from indirectly or consciously incorporating these elements into their own work. Katz and Riley (2018) outlined how these specific market failures pertain to postsecondary engineering education. That paper was a strategic move to employ the same logics underlying the general shifts in higher education in order to highlight concomitant drawbacks to applying those shifts in engineering education. It was designed to emphasize some of the unintended negative consequences of employing this market logic to education so that nobody confuses markets with a foolproof mechanism to coordinate education systems. The argument started with the inherent assumptions of that market logic and followed them until finding presumably unintended consequences and inherent contradictions. Along with calling attention to these problems, the paper also reviewed potential solutions, as suggested in the standard economic literature. The following sections use the same approach to discuss these phenomena in engineering education, providing supplemental examples and research questions to explore these market failures.

8.A. Public goods. Public goods are those which are both non-rivalrous and non-excludable (Stiglitz, 1982). A canonical example is clean air or national security. In higher education, research in publicly available publications is a classic example (Stiglitz, 1999). Within engineering education, the phenomenon of public goods provision can manifest from myriad dimensions of engineering education research. For a specific dimension, consider instructional resources. Concept inventories – e.g., Statics concept inventory (Steif & Dantzler, 2005), Dynamics concept inventory (J. Lane et al., 2005) and thermodynamics concept inventory (Olds, Miller, Streveler, & Nelson, 2004) – are an example of instructional resources from engineering education research that qualify as public goods. Assuming faculty members have internet access, one instructor's use of a concept inventory does not preclude a separate instructor's use of that same concept inventory. This is important because typical public good provision theory predicts that public goods are commonly under-provided, regardless of the degree of centralized planning (Besley & Coate, 2003). In order to boost their provision, financial subsidies and reputation can be used to encourage providers (Andreoni & Bergstrom, 1996). For instance, the National Science Foundation commonly supports the development of these concept inventories (Garvin-Doxas, Klymkowsky, & Elrod, 2007). Consequently, it would behoove those individuals in positions to make decisions about resource allocation to consider subsidizing the creation of these resources. The upshot is a general justification for intervention on the part of administrators and others in positions of authority.

Other examples of instructional resources as public goods include ethics case studies and lesson plans for K-12 classrooms. Engineering ethics case studies can be found online on the NAE Online Ethics Center website. As one participant stated, *"I know and I hope that there is a database for engineering ethics case studies…I was reviewing some of them so I know that some of those exist. There are people using them because I could see statistics of how many people access them, but I'm not sure how they use them or necessarily where." [Int 02]*

Those ethics cases are freely available to the public. As with the concept inventories, one faculty member's use of a case does not preclude another faculty member from using that case (non-rivalrous condition). Similarly, as long as someone has access to the internet then there are no barriers for them to find and use the case studies (non-excludability condition). The same is true for K-12 engineering lesson plans published online by organizations like the American Institute of Aeronautics and Astronautics (AIAA). The same participant described the AIAA's contributions of these public goods:

"They are really active for K-12. They create micro lessons." [Int 02]

Again, those instructional resources are available online for public use. In this scenario, rather than a governmental organization or individual actors sponsored with government funding producing these items, a professional organization is producing them. Nonetheless, they are public goods. In the political economy of engineering education, there is an open question of how to increase the provision of these public goods.

Sample Questions: How have government agencies allocated financial resources for the provision of public goods related to engineering education over the past century? For example, to what extent do the justifications for land grant universities and the G.I. Bill rely upon this idea of a public good – producing knowledge or a more highly educated population that has the downstream effect of benefitting larger populations, similar to a positive externality (except not exactly the same because most taxpaying citizens are indirectly party to those transactions since government funds support those initiatives).

8.B. Principal-agent problem. A principal-agent problem is a scenario in which one person (the principal) prefers a specific action or outcome but they must rely upon another person (the agent) to make that come to fruition (Miller, 2005). In engineering education, faculty members (the agents) might know that members of their department's industrial advisory board (the principals) annually express specific requests for the department to modify the undergraduate curriculum. Specifically, members of the industrial advisory board may want the engineering department to teach more communications and teamwork skills. Those advisory board members, whose companies may eventually look to hire the department's graduates and therefore want their future employees to have those skills, cannot teach the undergraduate courses themselves; instead, the board members rely upon the department's faculty members to incorporate lessons on those skills in their respective classes. Faculty members, on the other hand, may prioritize teaching other technical skills over communication skills. This disjunction between the board members' and the faculty members' preferences creates the principal-agent problem.

The principal-agent problem is not a rare phenomenon. Indeed, there is an entire body of literature that focuses on this idea in other settings, both educational and non-educational (Laffont & Martimort, 2002; J. E. Lane & Kivisto, 2008; van Ackere, 1993). Looking more broadly, the same pattern – some combination of social, political, and/or economic factors engenders a dynamic in the engineering education system, some people vaguely recognize it, but frequently they lack the vocabulary and framework(s) to think more critically about what they are experiencing – applies to myriad other phenomena throughout the engineering education system. The conceit of this paper is the following: we can improve this state of affairs by putting a name to phenomena such as the principal-agent problem any numerous others like it. Doing so would not only enable faculty members (or advisory board members) to more readily recognize specific dynamics but also help point them to potential solutions identified in the extant political economy literature. Why not leverage the work and ideas from fields likes economics or political science to address challenge facing the engineering education community?

The principal agent problem surfaces if faculty members have diverging priorities and understandings of how to prepare engineers. As one participant stated, engineers on the department's industrial advisory board

> *"tell us they want that economics should be required. They want more public speaking. They want more accounting and more business classes, because most of them in their careers are the managers of their offices and that's the information that they wish they had" [Int 17].*

More generally, as another faculty member described the relationship,

> *"Engineering programs need to address the skills desired by the companies hiring their students" [Int 10]*

In these scenarios, the principal-agent problem phenomenon manifests as described above, with companies as the principals, engineering programs as the agents, and only loose coupling between those two groups.

Sample Questions: Where else are there principal agent problems in the engineering education system? What are the negative consequences of these disconnects between the interests of some groups and their dependence on others to make those interests come to fruition, as with industry working through ABET working through individual engineering programs, for example? For example, Akera (2016, 2017) situates this influence of ABET in the context of broader changes in engineering education.

8.C. Information asymmetries. As alluded to in the above section on the general political economy of education, information asymmetry can permeate throughout engineering education. Sometimes this phenomenon is by design. For example, before a summative assessment faculty members will know the specific questions asked on the assessment while students do not – one person or group knows more than the other group. Not only is this by design, but it is expected. Other times, however, the information asymmetry phenomenon may be less intentional. For example, programs may target students to recruit into their programs and in that recruitment process offer incomplete information about the typical nature of the profession or educational experience. Indeed, programs may represent an engineering degree as one rife with active learning opportunities and ample hand-on experiences, but in reality this may only represent the first and final semesters of the program, corresponding to the introduction to engineering course and the senior capstone course, respectively. One participant described the cold reality that students in the participant's program encounter in their sophomore year. After they have been misled by their first-year, hands-on courses students' expectations of similarly engaging pedagogy are undermined by large lecture-style classes in year two:

> *"they get to second year and it's like statics and dynamics and it's taught in a very traditional format. It's like, 'I thought it was going to be all this kind of build stuff'" [Int 13].*

This statement demonstrates the degree to which programs may possess asymmetric information about the nature of their programs. Of course, a more trite example of asymmetric information is the contents of an exam, for which some students will actually pay and risk penalty to obtain (Teixeira & Rocha, 2010).

In many areas within the engineering education system one can find examples of asymmetric information between actors. The more consequential question to investigate when characterizing the political economy of engineering education is the causes of these asymmetries and their effects. In other words, are these asymmetries incidental or are they the result groups intentionally withholding information?

Sample Questions: How do information asymmetries between students and their programs affect their preferences and exhibited behaviors related to major choice and persistence? Does more complete information lead to different student behavior?

9. Collective action. Collective action, or coordination problems, arise when concerted effort is required of a group in an organization in order to accomplish a particular task or generate a shared resource (R. Hardin, 1991). This is part of the political economy of engineering education because collective action relies upon individuals forming working relationships to spend time, money, and energy in accomplishing tasks typically established with particular economic incentives in mind. A problem can arise, however, when individual freedom and efforts are encouraged more than group efforts, as happens with some organizational structures, incentives, and philosophies. In engineering education, the collective action phenomenon can occur when faculty members organize themselves cohesively within a department to coordinate content or a specific topic across the curriculum. For example, with engineering ethics, this can arise in efforts to adopt an "ethics across the curriculum" model for teaching ethics.

> *"I think who should is I think that the College of Engineering faculty should more collectively take ownership for that instruction. There should be a more systematic approach to the material that's taught or at least to the approach that is used to teach that content". [Int 20]*
>
> *"We haven't tried to coordinate between courses. I think again, it just goes back to that coordination means really hard in general and that it's really hard in our department right now. Um, but the, amongst the faculty who are interested in it, you know, whatever personal, personal interest or whatever have their own personal reasons to do it, we can talk amongst ourselves so we are aware of what each other are doing." [Int 14]*

The consequences of this lack of collective action and consequent relegation of particular topics to certain areas of the curriculum rather than a more measured integration can be a devaluing of that topic:

"I think by not integrating that really well across the curriculum, we send a message to our students that it's not important and it's an afterthought and that it's irrelevant to like the whole, like real work of engineering." [Int 14]

The benefits of collective action are further touted by another participant:

"I think that bringing different opportunities to teach ethics into all the courses and the curriculum is probably a better way, because then students would see it more consistently and not see it as a standalone thing, which is addressed separately." [Int 20]

This demonstrates the need and potential effects of collective action in engineering education systems and the general relevance of collective action in the political economy of engineering education.

While coordination leading to collective action is important for achieving certain student learning outcomes, an ethos in engineering education that emphasizes the liberty of the individual over any semblance of collective consciousness may diminish that possibility. Faculty members could be pushed toward egoism in lieu of altruism or a team mentality. Instead of faculty working together, the political economy of engineering education facilitates compartmentalization of the faculty, the curriculum, and the subject matter therein. This same ideology extends to the next phenomenon: the tragedy of the commons.

Sample Questions: What are some examples of departments and colleges that have successfully institutionalized collective action across their faculty? Are their scaling problems that make solutions in one context infeasible in other contexts due to size differences between the settings?

10. Tragedy of the commons. A tragedy of the commons can occur when there is a common pool resource (the commons) upon which multiple people can place demands (G. Hardin, 1968). In the absence of coordination, there is a possibility that the aggregate effect of individuals acting in their own self-interest can deplete the resource. It is a phenomenon that emphasizes the importance of coordination for collective action. Hardin's canonical example is an open pasture (i.e., the commons) with multiple herders whose animals graze the land. If all the herders act in a self-interested manner, then they might exhaust the pasture as a resource through over-grazing, thus creating the tragedy of the commons. An education-specific example might comprise student's time. In this example, faculty members are the individuals placing demands on students' time by assigning homework and other class-related tasks, potentially to an excessive degree.

Without specific coordination among the faculty members, the resource – students' time – can become depleted, potentially to the detriment of the student's physical and mental health (Jacobs & Dodd, 2003; Robotham & Julian, 2006). As a one study on student stress factors described the situation from a study participant's perspective, "Another student expressed frustration with a workload resulting from "the uncanny ability of professors to assign large assignments concurrently" with other classes" (Dusselier, Dunn, Wang, Shelley II, & Whalen, 2005). Unfortunately, there is no requisite fail-safe in the absence of ad hoc faculty coordination to forestall this problem.

Again, the atomization of the faculty through a neoliberal philosophy that emphasizes the individual – how many publications has the individual produced, how many students has the individual graduated, how many positive course evaluations has the individual received – to the detriment of the group may be creating these deleterious consequences. The political economy of higher education, and engineering education by extension, creates these conditions. The basic idea is that a focus on oneself can be alluring and feel empowering, suggesting you are the driver of your own destiny; however, that egoistic behavior is not without consequences (which is to say nothing about the falsity of those self-centered perceptions from the outset). Specifically, if faculty members focus on incentives that reward individual behavior rather than coordinated efforts, as the political economy of engineering education may indeed entice faculty members to do, then this fosters conditions for the tragedy of the commons.

Sample Question: With this conceptual framing, one might ask: Is there in fact a tragedy of the commons as it relates to student time? In particular, do faculty members who act in isolation from each other draw upon students' time more than faculty members who act in concert with each other in a more coordinated fashion? Moreover, are the typical palliative solutions to tragedies of the commons applicable/suitable for the engineering education system? This line of questioning may be of interest to anyone interested in student mental health, stress, time management, and pressures inducing students to leave engineering. It could also potentially provide insight into a potential mechanism to improve students' experiences if coordination does indeed help avoid this hypothesized tragedy of the commons.

Since a canonical tragedy of the commons arises from individuals acting out of self-interest and drawing upon a shared resource, a context in which faculty members are incentivized to act out of their own self-interest could theoretically generate these tragedies of the commons. Thus, any research into this phenomenon in the political economy of engineering education would need to identify the common pool resource (e.g., student time or attention) and the instances in which actors in the system (i.e., faculty members) are drawing upon that resource without considering the ramifications for others actors.

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