FACULTY PERSPECTIVES AND PRACTICES RELATED TO ENGINEERING ETHICS AND SOCIETAL IMPACTS EDUCATION

by

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Abstract

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Faculty Perspectives and Practices Related to Engineering Ethics and Societal Impacts Education

Thesis directed by Professor Angela R. Bielefeldt

Across the world there is increasing emphasis on developing engineering students' understanding of ethical responsibility and awareness of societal context. This trend has necessitated a closer examination of the role that engineering faculty play in the integration of ethics and societal impacts (termed ESI) in curricula. Like all instructional decisions, those related to if, how, and where to teach ESI are the result of a complex combination of factors that are both within and outside of the control of the individual educators.

This research applied the Academic Plan model (Lattuca & Stark, 2009), which conceptualizes course planning in higher education to understand influences on engineering faculty's practices and perspectives related to ESI. This framework posits that personal internal factors, environmental influences, and external forces shape educational processes and outcomes through curriculum design. The Academic Plan provided the structure of this dissertation so that each of the three chapters explored a different component of the model: individual internal influences, academic environment, and sociocultural environment. First, in-depth and semi-structured interviews with engineering faculty who teach ESI illuminated the personal beliefs and interests and academic and professional experiences that shaped their instruction. Second, a case study exploration of two engineering departments elucidated the influence of academic environment and culture on engineering faculty's teaching related to ESI. Third, a broader view of environment through a cultural lens explored similarities and differences in the ESI practices and perspectives of educators in Anglo and Western European countries. Taken together, these results build on the Academic Plan to provide granularity on influences of significance in ESI

education in engineering. The findings indicate both conflicting and complementary influences on ESI course planning and how factors at the personal and environmental level can be leveraged to support faculty's teaching of ESI and thus students' education on these important considerations.

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Chapter I: Introduction

Introduction

Engineering is about “nuts and bolts and people” (Faulkner, 2007, p. 331). Although the physical components render the most visible impact of engineering, it is the “social and ethical connections [that] are as important, if not more so, as electrical and mechanical ones” (Sheppard, Macatangay, Colby, & Sullivan, 2008, p. 9). Part of the responsibility of the engineering profession is fostering an understanding of these social and ethical impacts and how engineering and technology fit into the broader context. Since “formal education may be the only institutionalized training where future engineers learn ethics and the responsibilities of their profession,” it is imperative to develop an awareness of ethical responsibility and societal context in engineering curricula (National Academy of Engineering [NAE], 2017, p. 7). Engineering faculty play a key role in integrating social, ethical, and technical considerations and preparing students to understand ethics and societal impacts (termed ESI). ESI is inclusive of microethics, the decisions and responsibilities of individual engineers such as adhering to codes of conduct; not accepting bribes; and performing within their area of competence, and macroethics, the broader responsibilities of the engineering profession to society, such as taking into account the impacts of technology, social justice, and sustainability (Herkert, 2005). The recently revised accreditation criteria in the United States appear to bridge micro and macroethics in criterion 3 outcome 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” (Accreditation Board of Engineering and Technology [ABET], 2018).

This responsibility is magnified with the accelerated rate of technological development and global interconnectivity. Emerging technologies like nanotechnology (Abuelma'atti, 2009) and autonomous systems (Institute of Electrical and Electronics Engineers [IEEE], 2018) will present ethical challenges that are still being discovered to the next generation of engineers. As a result, there is growing need to integrate ESI in engineering curricula and engage engineering faculty in this process. Despite this requisite motivation, there are a number of barriers that prevent the widespread and effective inclusion of ESI in undergraduate engineering curricula. Challenges include "an overcrowded engineering curriculum makes separate, standalone engineering ethics courses difficult; moreover individual ethics courses risk marginalization, while modules within existing courses risk dilution…there is low faculty knowledge, comfort, and facility with teaching ethics… [and] facilitating learning at scale" (NAE, 2017, p. 12). Given the curricular restraints on time and limited opportunity to teach ESI in dedicated courses,

> the greatest challenge… will confront engineering faculty. Since it is unlikely that there will be many instances where required courses in engineering ethics are taught, it is incumbent upon the engineering community to see that ethical problems, standards of conduct, and critical thinking skills are adequately developed within the context of technical courses (Herkert, 2000, p. 311).

Engineering faculty are uniquely positioned to teach ESI because they have the greatest exposure to students in the curriculum dominated by technical courses; they serve as professional role models; and they can bridge educational content and its practical application. Because of both the responsibilities that engineering educators share and challenges they face, my dissertation is focused on the role of engineering faculty in ESI education. To support the broader integration of ESI into the engineering curriculum and improve teaching efficacy, it is important to understand the factors that shape ESI instruction. My dissertation is focused on the influences that affect faculty decisions regarding if, how, where, and why they teach ESI to engineering and computing students. My dissertation examines the ESI instructional practices of engineering educators using a mixed-methods approach (Borrego, Douglas, & Amelink, 2009) and Academic Plan framework (Lattuca & Stark, 2009).

Study Purpose

My dissertation research is situated within the National Science Foundation (NSF) funded project titled "Collaborative Research: Efficacy of Macroethics Education in Engineering" and supported under grant Nos. 1540348, 1540341, 1540308, and 1755390. This work is the joint effort and scholarly contribution of Dr. Angela Bielefeldt (principal investigator [PI]), Dr. Chris Swan (PI), Dr. Nathan Canney (PI), and Dr. Daniel Knight (evaluation specialist). The broader study employed a mixed-methods design to explore ESI in engineering and computing education. A survey of faculty and academic staff was developed and distributed to understand if, where, and how educators integrate ESI in curricular and co-curricular settings. Approximately 1400 responses were collected in spring 2016 and results have been published (Bielefeldt, Polmear, Canney, Swan, & Knight, 2019; Bielefeldt et al., 2018a, 2018b, 2018c, 2017a, 2017b, 2017c, 2017d; Canney, Swan, Polmear, & Knight, 2016; Knight, Bielefeldt, Swan, Canney, & Polmear, 2018; Knight et al., 2016). On the survey, respondents were given the option to provide their email addresses to be contacted for a follow-up interview. Of the 230 who volunteered, I contacted 52 and completed 37 interviews. The interviews were designed to learn more about the settings in which the participants teach ESI and the approaches they employ to identify exemplary practices. Results from the interview phase have also been published (Polmear, Bielefeldt, Knight, Canney, & Swan, 2018a, 2018b, 2019). From this effort, I wrote summaries of 35 current examples of ESI instruction. The interviewees and research team evaluated the examples via an online survey based on demonstrated novelty, transferability, strength of assessment, and overall interest (Bielefeldt et al., 2018d). From this feedback, 17 examples were selected for in-depth case study analysis and those educators were emailed to continue their participation in the study. Eleven educators agreed to participate and have their setting studied in further detail, which variously included student pre- and post-surveys, alumni surveys, additional faculty interviews, on-site observations, student focus groups, and student work assessment. This broader project revealed the key role that engineering faculty play in ESI education, the influence of the environment in which they work, and the complex web of factors that shape their teaching. As a result, my dissertation research focuses on the faculty perspective to understand influences on their ESI education practices.

The purpose of this study is to understand how personal background, educational and professional training, and environment influence decisions regarding ESI instruction. Since engineering is situated at the intersection of social and technical considerations and since its impacts reach all aspects of communities, engineers must be trained to understand the implications of their work in various contexts. This macroethical responsibility should be engrained in students during their undergraduate education, which serves as the primary, if not only, formal ethical training that most engineers will receive (NAE, 2017). Integration into undergraduate education is especially important since unlike other professions including law and medicine, engineering only requires a four-year degree (National Society of Professional Engineers [NSPE], n.d.). Furthermore, without the impetus of accreditation, graduate engineering programs may offer minimal coverage of ethics and societal context, which could explain in part why graduate education in ESI has been viewed as deficient (Bielefeldt et al., 2018b, 2018d). Although professional engineering (PE) licensure can mandate continuing education related to ethics, requirements vary by state and licensure is less common for some engineering disciplines (NSPE, n.d.).

This responsibility to teach and train the next generation of engineers is shouldered by engineering faculty. Their decision regarding what and how to teach is the confluence of complex and interrelated factors. Understanding these influences, how they connect, and how they are manifested in ESI-related teaching practices will inform curriculum theory while also supporting the broader dissemination and implementation of ESI teaching. By understanding what shapes educators' teaching practices, we can more effectively leverage their personal backgrounds and environmental characteristics in professional development. Although there are many challenges to effective and widespread ESI education in engineering in the United States (NAE, 2017; Newberry, 2004; Polmear et al., 2018a), there are also a number of leverage points on which to capitalize, starting with the educators themselves who are tasked with this ever-important responsibility.

Organization of the Dissertation

This dissertation is structured as three separate journal articles. Each article, presented as Chapters IV to VI, includes background, theoretical framework, research questions, methods, results, and discussion. As a prelude to the individual articles, Chapter II provides a literature review on the importance of ESI education, the current state of ESI education in the United States, challenges confronting engineering educators related to teaching ESI, and influences on course planning.

Chapter III introduces the design of the study including the theoretical framework, methodology, and methods. The data collection methods, participants, and data analysis methods are described for each article.

Chapters IV through VI are the three journal articles, which are structured around the theoretical framework. Each chapter makes unique contributions to engineering education while being linked through the Academic Plan model. Chapter IV explores how individual-level influences, such as personal beliefs, academic training, and professional experience shape engineering educators' ESI instruction. Chapter IV is in preparation for the *Journal of Engineering Education*. Chapter V examines the effect of academic culture and environment on engineering faculty members' ESI practices and perspectives. Chapter V is in preparation for *Engineering Studies*. Chapter IV investigates the impact of cultural environment on engineering educators' ESI outcomes by comparing those at institutions in the United States (US), non-US Anglo (Australia, Canada, Ireland, United Kingdom, and New Zealand), and Western Europe (Austria, Denmark, Finland, France, Germany, Israel, Italy, the Netherlands, Norway, Portugal, Spain, Sweden, and Switzerland). Chapter VI was published in the *European Journal of Engineering Education*. These three chapters vary in format in compliance with the journals to which they are being submitted.

The dissertation concludes with Chapter VII, which ties together the threads of the internal influences, environments, and educational outcomes as they relate to educators' practices and perspectives regarding ESI education in engineering. The final chapter includes a summary, discussion of implications, and section on opportunities for future work.

Chapter II: Literature Review

The literature review is split into four sections: the importance of ESI education, the current state of ESI education, challenges confronting engineering faculty teaching ESI, and influences on course planning.

The importance of ESI education

Engineers, like all professionals, "provide a worthwhile service in the pursuit of important human and social ends…[and] work within ever-increasing complexity and changing conditions" (Sheppard et al., 2008, p. 4). The nature of their work and the context in which it is embedded necessitate an understanding of ESI in engineering practice and education. Looking forward in 2004, the National Academy of Engineering (NAE) claimed, "The future is uncertain. However, one thing is clear; engineering will not operate in a vacuum separate from society in 2020 any more than it does now" (NAE, 2004b, p. 27). As a result, the engineer of 2020 must adapt to technological breakthroughs and respond to challenges in the political, economic, and social contexts driven by unprecedented technological growth and "tightening global linkages" (NAE, 2004b, p. 1). To not only respond to technological and social changes, but to stay ahead of them, engineers "will be required to use new tools and apply ever-increasing knowledge… all while considering societal repercussions and constraints within a complex landscape of old and new ideas" (NAE, 2004b, p. 43). The report anticipated the importance of ESI in engineering practice and education with sustainability and ethics noted as aspirations for future engineers. As we approach 2020, the need for an understanding of ethical responsibility and societal context continues to be realized. Currently and into the future, there is "the need for engineering ethics to focus more on macroethical issues, rather than microethical or individual ethical issues" (NAE, 2004b, p. viii).

The need to develop these professional competencies is also recognized in industry. McGinn (2003) surveyed practicing engineers and found 80-90% believed "current engineering students [were] likely to encounter significant ethical issues in their future engineering practice" and more than 90% thought engineering students "should… be exposed during their formal engineering education to ethical issues of the sort that they may later encounter in their professional practice." Reflecting on their past training and current work, practicing engineers indicated that they "had little opportunity in their professional studies for learning how to come to grips with such issues, wish they had had more adequate preparation for doing so, [and] believe that current engineering students will also be confronted by such issues" (p. 538). However, the expectations of the profession and the realities of engineering education appear to be misaligned. Engineering practice involves open-ended problem solving, which includes a range of socio-technical considerations while "U.S. engineering education is primarily focused on the acquisition of technical knowledge" (Sheppard et al., 2008, p. 4). This model of engineering education that has persisted in the United States contributes to the disconnections

> between the education of engineering students regarding ethical issues in engineering… and the realities of contemporary engineering practice… these divergences impede the recognition of ethical issues and of specific moral responsibilities of engineering in concrete professional practice (McGinn, 2003, p. 517).

As a result, there is a need to better understand the realities of engineering education and where ESI fits in that paradigm.

The current state of ESI education in the United States

Hess and Fore (2017) conducted a systematic review of engineering ethics interventions and concluded "there is limited empirical work on ethics education within engineering across the

United States" (p. 1). Analysis of 26 articles published between 2000 and 2015 revealed that 65% of the described interventions were motivated by ABET accreditation and that university, school, or departmental efforts (50%), national efforts (46%), and societal improvement (46%) were also cited as justification for the interventions. Nearly all of the interventions analyzed in the review included learning goals pertaining to ethical sensitivity or awareness (96%) or ethical judgment, decision-making, or imagination (89%). A smaller number of the interventions (27%) described learning goals related to ethical behavior. The most commonly cited pedagogical strategies were codes of ethics, case studies, and discussion or debate. These results align with previous studies on the prevalence of case studies in engineering ethics education (Colby & Sullivan, 2008; Harris, Davis, Pritchard, & Rabins, 1996; NAE, 2004).

There are a number of approaches and settings for the integration of ESI into the engineering curriculum. One curricular model is ethics across-the-curriculum, the holistic and intentional integration of ESI into courses throughout the program (Colby & Sullivan, 2008; Harris et al. 1996; Hess & Fore, 2017; Li & Fu, 2010). A survey of engineering and computing educators asked respondents where they believe undergraduate students in their program learn about ESI and 41% (total n=1147) indicated across-the-curriculum, which was defined as core technical courses and at least three other course types (Bielefeldt et al., 2017c). ESI can be taught in dedicated courses (Drake, Griffin, Kirkman, & Swann, 2005; Hashemian & Loui 2010; Zandvoort, van de Poel, & Brumsen, 2000), taught via modules (Hess & Fore, 2017), or micro-insertions (Davis, 2006) in existing courses. In the United States, first-year introductory courses (Bielefeldt et al., 2017a) and senior capstone design (Bielefeldt et al., 2017b) are common curricular settings for ESI integration. ESI education varies globally based on national differences in accreditation criteria, educational systems, professional standards, and cultural contexts (Brumsen, 2005; Didier, 1999). These differences and how they impact the current state of ESI education at Anglo and Western European institutions will be explored in Ch. VI, which examines ESI practices and perspectives through a cultural lens.

Despite the range of integration strategies and curricular approaches associated with ESI, students' instruction on this topic has been widely viewed as deficient (Bielefeldt et al., 2018a; Colby & Sullivan, 2008; McGinn, 2003). The largest assessment of engineering students' ethical development used the Student Engineering Ethical Development (SEED) survey (Finelli et al., 2012). The 3914 respondents, who were all undergraduate engineering majors attending 18 institutions, indicated high quality and quantity of ethics exposure in curricular and co-curricular settings. However, students' knowledge of ethics (as indicated by performance on Fundamentals of Engineering (FE) exam style questions) was "surprisingly low" (p. 487). Additionally, students' ethical reasoning was "lower than their peers in other fields" (p. 487), and almost 80% of students reported engaging in unethical behavior (as measured by seven types of self-reported cheating behaviors). These results indicate the need to change undergraduate ethics education including improving students' ethical knowledge, reasoning, and behavior.

Challenges confronting engineering educators teaching ESI

To improve ESI education and support those who are teaching it, it is important to understand the challenges that engineering faculty face in this endeavor.

Role of ESI in curricula

The structure of engineering education can serve as a barrier to the integration of ESI. The focus on math, science, and engineering courses privileges technical content over societal and ethical considerations. Humanities and social science courses, which occupy 13-20% of engineering curricula and can serve as opportunities for ESI instruction, are often divorced from technical issues (Leydens & Lucena, 2017). Design courses can emphasize sociotechnical thinking but these courses usually occupy less than 15% of the engineering program (Leydens & Lucena, 2017). Although design seems like a natural setting to dually consider engineering and its ESI implications, 38% of engineering and computing faculty who responded to a national survey reported that ESI is not taught in the capstone design course in their program (Polmear et al., 2019). This could be due in part to the tension between the formal and hidden curriculum in engineering. The formal curriculum describes what the instructors and institutions state is taught (Hafferty & Gaufberg, 2017). ESI has been part of the formal curriculum as an outcome since the adoption of EC2000 by the ABET Board of Directors in 1996 (Lattuca, Terenzini, & Volkwein, 2006). Prior to the adoption of EC2000, "an understanding of the ethical, social, economic, and safety considerations" was included in ABET accreditation criteria (Stephan, 1999) with the emphasis on what is taught, not what is learned (ABET, n.d). The hidden curriculum describes what is "neither formally announced nor intended" but relates to the "gaps or disconnects between what faculty intend to deliver (the formal curriculum) and what learners take away from those formal lessons" (Hafferty & Gaufberg, 2017, p. 35-36). The hidden curriculum can influence engineering educators and their ability to teach ESI through a number of mechanisms such as promotion and tenure, cultural attitudes, and professional socialization (Polmear et al., 2019)

Lack of consensus

One of the fundamental challenges in ESI education is the lack of consensus "regarding which strategies are most effective towards which ends, nor which ends are most important" (Hess & Fore, 2017, p. 1). Ratings of "exemplars" of ESI instruction revealed that ESI educators had widely divergent opinions in what constituted novel, transferrable, and impactful (Bielefeldt et al., 2018d). Without a common understanding of the aims of ESI education and how they should be achieved, engineering programs and educators can struggle to fulfill these student outcomes. Despite the recognized importance of ESI in engineering education from accrediting bodies and industry stakeholders, faculty have varying perceptions on its role in the curriculum and their responsibility to teach it. In a survey of engineering instructors at four Canadian institutions, Romkey (2015) found that 33.2% of respondents reported that Science, Technology, Society, and the Environment (STSE), an educational movement that overlaps with macroethical ideals, does not happen and is not important. A similar percentage (32.7%) claimed STSE does not happen but is important. The results also indicated a nearly even split between faculty in terms of whether STSE should be taught in math, science, and engineering science courses, suggesting a divide in educators' support of the across-the-curriculum approach. The majority of the respondents believed STSE should be taught by instructors of technology and society studies courses (93.9%) and engineering ethics courses (95.7%). An international survey of 600 electrical and computer engineering academics revealed that 36% of respondents do not teach moral/ethical reasoning and 48% do not assess it (Lord, Ohland, Froyd, & Lindsay, 2015). STSE and moral/ethical reasoning share similarities with ESI in content and aim, and the results of related research point to a lack of consensus on these topics and initiative of educators to integrate them into their own courses.

Lack of engineering faculty knowledge

One commonly cited challenge in engineering ethics education is engineering faculty's lack of knowledge in this domain and training to integrate the topics into their courses (Herkert, 2000; NAE, 2004; NAE, 2017). With limited exposure in their own background (especially for those educated before ABET EC2000) or limited industry experience to bridge engineering in practice and the classroom (Fairweather & Paulson, 1996; Gupta, 1988), engineering educators can feel ill-equipped to discuss ESI. Another potential barrier is the emphasis on competence in engineering and "engineers are generally not experts in addressing the social and ethical implications" (NAE, 2004, p. v). This creates a tension since the "the exercise of professional responsibility requires both competence and concern…engineers working beyond their competence are, for that reason alone, considered to be acting unethically" (NAE, 2004, p. 97-98). With a lack of incentive to pursue the training and development to effectively enter this space (NAE, 2017; Newberry, 2004), faculty have limited motivation. This challenge is compounded by a lack of student engagement, which can be evidenced on course evaluations where "students overwhelmingly rate the ethics component of the course as the least interesting, least useful, and the most trivial" (Newberry, 2004, p. 347). One of the primary uses of student evaluations is to aid in decisions regarding the retention and promotion of instructors (Ryan, Anderson, & Birchler, 1980). Student disengagement, and the ensuing low ratings related to ESI instruction, can affect educators' motivation and incentive to integrate these topics into their courses.

Despite these challenges, engineering faculty engagement is essential for ESI to be effectively integrated and prioritized in the curriculum (Colby & Sullivan, 2008). Engineering faculty have the greatest access to engineering students, compared to humanities or science specialists who could teach ESI, and the credibility to relate the relevance of these issues in the profession (NAE, 2004). In their book *Educating Engineers: Designing for the Future of the Field*, Sheppard and colleagues (2008) summarized the imperative for engineering faculty as "key stewards of the engineering profession. It is their job to… foster the social responsibility of the next generation" (p. 10).

Influences on course planning

The Course Planning Exploration survey, which informed the Academic Plan, sought to understand the factors that influence faculty members' planning of their introductory courses (Stark et al., 1990). The results from 2311 respondents indicated course planning is "most strongly influenced by discipline, scholarly and pedagogical background, and beliefs about education" (p. 1). Within their backgrounds, respondents rated teaching experience (90.8%), educational purpose (83.3%), scholarly preparation (69.8%), beliefs about teaching (69.2%), and practitioner experience (65.8%) as strongly influential. Only one third of the respondents indicated that instructional workshops and formal courses were strongly influential, and religious beliefs (13.4%) and political beliefs (6.1%) were the weakest influences.

Knight and colleagues (2016) drew on archival data collected by the Australian Learning and Teaching Council Discipline Scholars for Engineering and Information and Communications Technology to study the application of the Academic Plan in the engineering context. The survey was disseminated online in 2010-2011 to all engineering faculty at 38 Australian universities and collected responses from 591 educators at 30 universities. Items of the survey were mapped to the Academic Plan to understand the influence of internal and external factors on academics' course planning. At the personal level, interest and student satisfaction were reported as significant drivers for teaching practices. The results indicated a weak influence from external factors as measured by importance of, and familiarity with, competency standards from Engineers Australia (accreditation). However, there were differences by age (younger faculty were less familiar), industry experience (more experienced faculty were more familiar), and type of institution (faculty at research-intensive were less familiar). At the institutional level, the reward and recognition system was found to be important but differential according to gender (higher importance for women), first language (higher importance for non-native speakers), and industry experience (higher for those with less experience). The study concluded that individual and institutional considerations are imperative, bottom-up change can improve the educational culture, and professional development should capitalize on academics' inputs.

Katz and Knight (2017) used survey responses from 1389 engineering faculty at 31 institutions in the United States collected in 2008 to understand faculty views on ethics education. The survey asked, (1) "how much do you emphasize the importance of ethical beliefs in engineering?" and there were statistically significant interaction effects between gender and department, rank and department, and all three variables. There were statistically significant differences for department and gender in response to the question, (2) "how much do you emphasize examining beliefs and values and how they affect ethical decisions?" and for the question, (3) "to what extent do you agree that the engineering curriculum should cover ethical issues in multiple courses?" The primary course taught and number of years in industry before and during academia were also statistically significant predictors for the second and third survey items. The results indicated the influence of department (civil and industrial emphasized ethics more than electrical and mechanical) and gender (men placed higher emphasis on ethics instruction but women believed ethics should be in multiple classes). Industry experience was positively correlated with how much faculty emphasize ethical beliefs in engineering.

Environmental factors at various levels also shape course planning. Engineering education operates in a broad sociocultural context that influences the function and form of higher education (Lattuca & Stark, 2009). Although engineering is not a monolith, a culture of disengagement has been described within engineering education (Cech, 2014). This culture is propped up by pillars including the association of non-technical with not "real" engineering and technical/social dualism. The culture of disengagement pervades engineering programs by creating an environment that does not foster an emphasis on public welfare.

Another environmental influence is the students. Students' learning, engagement, and interest can influence educators' perceptions of their instructional efficacy, which in turn, shapes their teaching through the iterative feedback loop of course planning (Lattuca & Stark, 2009). Cech (2014) described that "one reason for the gap between the importance of the ethics education and the realities of the curriculum may be that students are not experiencing engineering ethics education in the manner that faculty feel they are delivering it" (p. 170). Holsapple and colleagues (2012) also found this discrepancy in ESI education. Faculty described teaching nuanced and complex issues while students reported learning black and white ethics like codes and laws. Faculty also believed they taught by example as ethical role models while students did not report learning about ethics in this way. Student responses and gaps between what is taught and what is learned influence the environment in which ESI education is embedded.

At the institutional level, "missions are an important influence on curriculum" (Lattuca & Stark, 2009, p. 69). A mission statement serves as symbolic and practical embodiment of an institution's core values and strategic planning. Although there is debate on the significance of mission statements from the "requisite first step in the road to organizational success" to "rhetorical pyrotechnics- pretty to look at…but of little structural consequence" (Morphew & Hartley, 2006, p. 456), they are ubiquitous in higher education. Mission statements "have an important influence on goal congruence between the organization and its employees" (Palmer & Short, 2008, p. 454), which can have implications for accreditation, accountability, and identity. Missions, such as those committed to public service, social justice, or sustainability, can impact the culture of the institution, which percolates into the practices and perspectives of the faculty within it. Another institutional influence, which can serve as the manifestation of the "institution's mission, philosophy, values, and culture" is the general education requirement (Warner & Koeppel, 2009, p. 241). The general education or common core usually consists of social and natural sciences, liberal arts, critical thinking skills, and global perspectives (Gaff, 1983). This area in the curriculum can include requirements for ESI-related subjects such as ethical reasoning, diversity, sustainability, and Science, Technology and Society (STS). However, institutions vary in the number and type of general education courses required for students. For example, research universities tend to emphasize composition and science and require little philosophy while Master's universities require the highest quantity of courses (Warner & Koeppel, 2009). Furthermore, research universities have been part of a trend of divorcing morality from the general education requirements since the early twentieth century (Reuben, 1996) leading to a marginalization of ethics (Glanzer, Ream, Villarreal, & Davis, 2004). General education can also vary across a campus with engineering students not always being mandated to meet the same requirements as other majors.

Gaps in literature and need for research

Ethics has been a formal part of engineering practice since 1914 through codes (American Society of Civil Engineers [ASCE], 2019) and education outcomes since 2000 through accreditation (ABET, n.d.). However, research in this area remains underdeveloped with opportunities for my research to make unique contributions to the literature. The exploration of ESI, inclusive of macroethics, is novel since most engineering ethics education emphasizes microethics (Conlon & Zandvoort, 2010; Herkert 2000). My focus on engineering educators' perspectives will also improve our understanding of ESI education since previous work has explored student perspectives (Finelli et al., 2012). There is a dearth of research on educators' practices and perspectives related to ESI and how internal and environmental factors shaped them.

Chapter III: Study Design

This study was designed to understand the impact of internal, environmental, and cultural influences on engineering faculty's ESI education practices and perspectives. The theoretical framework and methodology guided the data collection and analysis.

Theoretical Framework

The theoretical framework underpinning my dissertation research is the *Academic Plan in Sociocultural Context* (Lattuca & Stark, 2009), shown in Figure 1. This model was developed to understand faculty members' course planning. The Academic Plan is a derivative of the more general input-environment-output (IEO) model that was originally created by Astin (1993) and has since been applied in a range of contexts (e.g., Finelli et al., 2012). The Academic Plan draws from Toomb and Tierney's (1991) conceptualization of curriculum as having three components: the content, context, and form (analogous to input, environment, and output). The framework builds on empirical studies including interviews with 89 faculty members (Stark et al., 1988) and survey responses from 2311 academics (Stark et al., 1990). The Academic Plan describes the range of factors that influence academics' teaching through curriculum, which is defined as the "academic plan purposefully constructed to facilitate student learning" (Stark et al., 1990, p. 2), and course planning, defined as the "decision-making process in which instructors select content to be taught" (Stark et al., 1990, p. 2). Their work demonstrated that educators' experiences, characteristics, and beliefs shape their course planning (content), their perceptions of the environment in which the course is taught (context), and the design of the course (form). The model was based on quantitative and qualitative data from faculty members who teach introductory courses in nine fields; engineering was not included. Knight and colleagues (2016) applied the Academic Plan to their study of engineering educators in Australia because it "frames teaching decisions as the result of a variety of complex interrelated forces" (p. 696). The model also "assumes that academics have a key role in determining strategies for teaching; their final curricular plans, however, are also influenced by a variety of forces both internal and external to their institutions" (p. 696). The Academic Plan provides examples of influences at the personal and environmental (both internal and external) levels and is intended to be a heuristic.

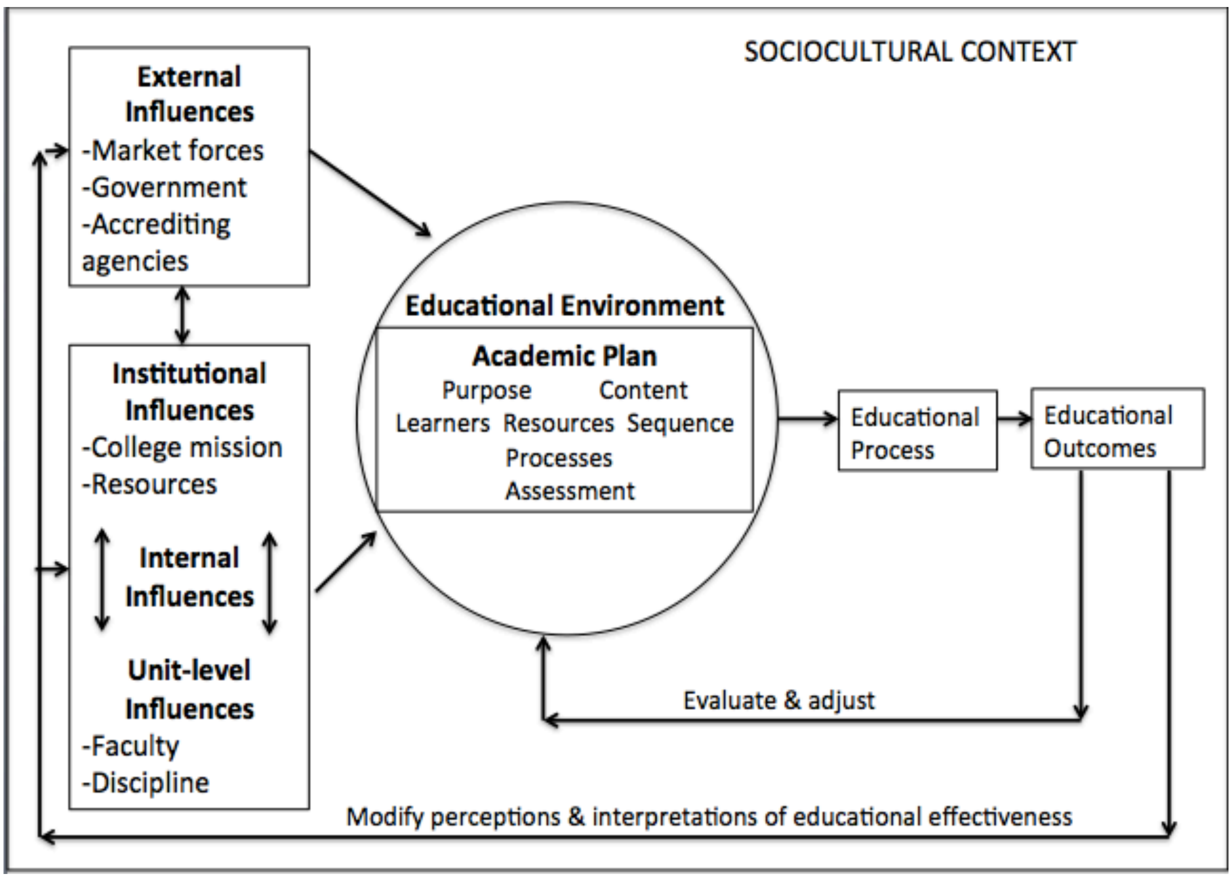

Figure 1: Academic Plan (Lattuca & Stark, 2009)

I applied this framework to my dissertation research to understand how educators' personal and educational background and institutional, departmental, and cultural environments influence their teaching of ESI. My three research questions and dissertation chapters are structured around this model to conceptualize the effect of intrinsic and environmental characteristics on decisions regarding ESI instruction.

Research Questions

The following research questions were explored as separate journal articles/chapters in my dissertation:

1. Chapter IV: What individual internal influences do engineering educators identify and describe as impactful in their teaching of ESI? How are these influences manifested in the instructional setting through ESI educational practices?
2. Chapter V: How do the academic environment and culture impact ESI education outcomes?
    a. What are engineering and computing faculty members' perceptions of the importance of ESI education in the two engineering departments?
    b. What are the institution, college, and department cultures experienced by engineering and computing faculty in the two departments related to ESI education?
    c. What are the personal instructional practices and perspectives related to ESI education of faculty in the two departments?
3. Chapter VI: How does cultural environment affect ESI outcomes?
    a. Do educators' perceptions of the **sufficiency** of ethics education of undergraduate and postgraduate engineering and computing students differ among those teaching in the US, non-US Anglo, and Western European countries?
    b. Are there differences in the ethics **topics** incorporated into courses taught to engineering and computing students among educators teaching in US, non-US Anglo, and Western European countries?

c. What are educators' **perspectives** on the ethics education of engineering and computing students in the US, non-US Anglo, and Western European countries?

Methodology

Methodology is informed by the theoretical framework and research questions and helps link the research methods and desired outcomes (Crotty, 1998). I employed a mix-methods design (Borrego et al., 2009; Wheeldon, 2010) to explore ESI education in the Academic Plan framework. This approach "involved the collection or analysis of both quantitative and/or qualitative data" (Creswell, 2003, p. 212).

Chapters IV and V employed a case study approach (Case & Light, 2011; Yin, 2003) and this methodology was driven by the research questions (Borrego et al., 2009). Case study is advantageous when "a 'how' or 'why' question is being asked about a contemporary set of events over which the investigator has little or no control" (Yin, 2003, p. 9). For Chapter IV, which explored the impact of individual internal influences on engineering faculty, I used a multiple-case study design with each case being bound as an individual engineering educator. This approach enabled me to study in-depth the experiences and perspectives of each educator while also including educators that represented a range of personal and professional backgrounds. For Chapter V, which explored the influence of academic environment on ESI education, the multiple cases were defined as two engineering departments at different institutions. The two cases were selected to represent variation in culture (one that was initially described in interviews as supportive of ESI education and one that was described as resistant) to examine a range of settings (Flyvberg, 2001). For both of these studies, the case study approach was explanatory (Yin, 2003) because I aimed to elucidate the influences that shaped practices and perspectives related to ESI education in the context of the Academic Plan model. Both studies also employed an embedded approach (Yin, 2003) since I was interested in understanding the internal influences on ESI education (as opposed to all of the backgrounds and beliefs that shaped the educators as people) and the academic environment and culture related to ESI education (instead of examining the departments holistically) for Chapter IV and V, respectively. Although the case study methodology has been criticized for perceived issues with generalizability, Case and Light (2011) argue "the concrete, context dependent nature of the knowledge which case studies unearth… is precisely the cause of its methodological strength" (p. 191). As a result, the methodology is especially apt for applications related to teaching and learning because it accounts for the "particular idiosyncrasies of the institution" (p. 191). Additionally, the goal of case study research "is not to provide a broad, generalizable description… but rather to describe a particular situation in enough depth that the full meaning of what occurs is made apparent" (Borrego et al., 2009, p. 57). I followed the design of quality case studies, outlined by Yin (2003), to mitigate potential limitations and improve the reliability and validity of my research design. The steps that I took within this framework are discussed under the "Reliability and Validity" section for the two individual chapters.

Chapter VI, which examined the influence of cultural environment on ESI education, I employed a survey research design. This approach is common in engineering education (Borrego et al., 2009; Olds, Moskal, & Miller, 2005). This study examined culture through the lens of clusters and explored similarities and differences between the US, non-US Anglo, and Western Europe. Since the cultural clusters in the study included 18 total countries, it was important to include a large sample whose opinions and experiences could most effectively be captured with a survey. The quantitative approach was also suitable since the data collected via "surveys administered to a sample or subset of the entire population, allow the researchers to generalize" which enables claims about the larger population (Borrego et al., 2009, p. 54). This approach fit the research questions to understand how environment at the broader, cultural level impacts ESI education with the intention of sampling a subset of educators in each cluster and extrapolating the findings.

The chapters have methodological distinctions but are all bound by the Academic Plan framework and exploration of ESI education through the engineering faculty perspective. The methods and participants are described by chapter in the following section. Methods are also included in the individual chapters but are presented in greater detail in this section to illustrate the overall approach of the research.

Methods

All methods were included in a protocol (#15-0326), approved by the Institutional Review Board (IRB) for Human Subjects Research, which was deemed exempt.

Chapter IV: Personal Internal Influences

The data for this study were derived from a series of interviews with engineering educators who currently teach ESI to engineering students.

Participant recruitment

Participant recruitment began with the survey campaign associated with the NSF-funded research project. As mentioned in "Study Design" respondents could volunteer for a follow-up interview by providing their email address near the end of the survey. There were 230 volunteers, and the project allocated funding for 36 interviews with each participant being compensated with a $50 Amazon gift certificate. Interviewee selection was based on a collaborative and iterative process involving Dr. Bielefeldt, Dr. Swan, Dr. Canney, Dr. Knight, and me. The research team was interested in including educators who taught a range of ESI topics using a variety of pedagogical and assessment strategies in different disciplinary and instructional settings. More detail on the selection motivation and rationale has been published (Polmear et al., 2018a). There were three waves of deliberation among our team that led to 52 invitations and 37 completed interviews, all of which I conducted between September 2016 and April 2017. Since the research project focused on ESI education in the United States (US), the interviews were primarily with educators in the US (n=35). To gather insight into perspectives and practices outside of the US, one interview was conducted with an educator in Ireland and one interview with an educator in Turkey was completed via email. These two international interviewees were not compensated for participating.

One of the primary purposes of the interviews was to identify exemplary settings to study in greater depth in the succeeding phase of the NSF project. Based on evaluations from the research team and interviewees (Bielefeldt et al., 2018d), 17 educators were invited to partner and 11 continued their participation in the project. Two educators expressed interest but declined due to time constraints, one declined due to retirement, one agreed to participate but did not follow through with assisting in data collection, and two did not respond to the email invitation. Of the 11 who continued their participation and were interviewed for a second time, seven were included in the analysis for Ch. IV. Since my research is focused on the role of engineering faculty in ESI education, the two who were non-engineers were not included. The follow-up with a third participant was limited to an informal conversation that was not recorded, thereby excluding that person. The interview with a fourth person did not include significant discussion of internal influences so this educator was also excluded. One criterion for case selection is including a diverse range of perspectives (Flyvberg, 2006). To this end, I added two other individuals for a total sample of nine. There two additions described internal influences not otherwise represented in the sample. One was a member of the initial group of 37, and the other was a colleague of a partner I interviewed during a site visit.

Data collection: Interview

I conducted interviews with nine engineering educators to explore the relationship between internal influences and ESI educational outcomes through course planning. The in-depth (Creswell, 2007) and semi-structured (Petty, Thomson, & Stew, 2012) interviews were designed to learn about the participants' ESI teaching and the experiences in their personal and professional background that shaped decisions regarding their instruction. The interview protocol is included in Appendix A. Due to the semi-structured nature of the interviews, not every participant was asked every question. I conducted all of the interviews from March 2017 to February 2018. The interviews were 27 to 83 minutes in length with an average of 43 minutes. The interviews were conducted in-person (n=5) or via Skype (n=4) and audio recorded. The participants were assigned a pseudonym using a random name generator to protect their confidentiality (Given, 2008). All of the participants are actively involved in teaching engineering students about ESI in curricular and/or co-curricular settings. A summary of participant characteristics is included in Ch. IV.

Data analysis

I used the audio recordings to transcribe the interviews with Trint (Trint, 2019). The transcripts were imported into Dedoose (Dedoose, 2019) for qualitative analysis. The interviews were analyzed using the constant comparative method (Glaser, 1965). This approach is the most common for qualitative analysis to identify themes in a data set (Leech & Onwuegbuzie, 2007). In accordance with this method, I initially read through the data set: the nine interview transcripts. The data were segmented into smaller parts as a unit of analysis. Each segment was labeled with descriptive codes that were developed deductively (*a priori* and looked for in the data) and inductively (emergent in the data). Throughout the coding process, comparisons between and within the interviews were made to refine the meaning of each code and ensure that appropriate categories were developed and applied throughout the data set (Boeije, 2002). After the first iteration, a preliminary codebook was developed that included themes of related codes. I then revisited all of the transcripts and modified the coding based on the codebook.

Reliability and validity

To increase reliability in the data analysis, I employed multiple coding (Barbour, 2001). This approach cross checks codes and interpretations across multiple researchers. To achieve this end, I used the negotiated approach (Garrison, Cleveland-Innes, Koole, & Kappelman, 2006). I reviewed two complete transcripts with Dr. Bielefeldt and Dr. Knight, and we collectively discussed the codes until alignment was reached. In addition to establishing agreement between multiple coders, I used the member check as a second strategy to increase reliability (Koelsch, 2013). The nine participants were emailed a preliminary schematic of the theoretical framework with variables that were discussed in the interview and coded in the analysis highlighted. A brief summary of the discussion related to each variable was provided. Questions were included in the summary and participants were given the opportunity to clarify and expand on the interview. An example member check is provided in Appendix B. Participants were also offered the full transcript for their reference. The tests and tactics outlined by Yin (2003) for quality case study design are shown in Table 1.

Table 1: Case study design

Test	Tactic	My approach
Construct validity: "establishing correct operational measures"	Use multiple sources of evidence	Interviews supplemented with biographical information available online
	Establish chain of evidence	Documented procedure from development of research questions, derivation of data, analysis of data, and formation of findings
	Have key informants review draft of case study report	Member checks
Internal validity: establishing a causal relationship	Do pattern-matching	Data was mapped to the theoretical framework to explore patterns and check for alignment between empirical and predicted pattern
	Do explanation-building	Connected data to theoretical proposition (Academic Plan) to explore causal links between internal influences and educational outcomes
	Address rival explanation	Acknowledged that educators engage in course planning and curriculum development in a sociocultural context and can also be shaped by external and environmental influences
External validity: establishing the domain to which a study's findings can be generalized	Use replication logic in multiple-case studies	Implemented same procedure for each case study
Reliability: study "can be repeated with the same results"	Use case study protocol	Operationalized procedures in IRB-approved protocol and applied consistently to all case studies
	Develop case study database	Created a repository with anonymized transcripts

Chapter V: Academic Environment

The case study methodology for Chapter V included the qualitative (interview and document analysis) and quantitative (survey) methods described below.

Data collection: Interview

Selection of the two engineering departments as case studies was based on interviews with the group of 37 educators who were part of the broader NSF study. The interviews included questions regarding institutional and departmental culture related to ESI education, which are included in Appendix C. Analysis revealed differential perceptions of the culture based on institutional characteristics such as type, control, and mission and departmental characteristics including size and discipline (Polmear et al., 2018a). I was interested in further exploring departments that appeared to represent divergent cultures despite having generally similar broad institutional characteristics. The chemical and biological engineering department at a public doctoral higher research university (Case A) and the electrical and computer engineering department at a public doctoral highest research university (Case B) were selected based on these criteria. While doing site visits as part of the broader NSF study, I interviewed two additional engineering faculty members in the department at Case A, and their perspectives corroborated the supportive culture described in the initial interview. I interviewed a second educator from Institution B, from a different department, as part of the group of 37 and perceptions of environment and culture paralleled those expressed in the interview with the faculty member from electrical and computer engineering.

The case study selection was based on the opinions of few educators, which could represent a bias. As ESI educators, the participants could also experience a different culture than others in the department who do not teach these topics. To gather more perspectives that could substantiate or disconfirm my initial understanding of department culture, I sought to interview more educators in each department via snowball sampling (Noy, 2008). I asked both of the educators to share the names and email addresses of colleagues in their departments who do not teach ESI or appear to not support it. The educator at Case A recommended three colleagues, and Case B educator suggested seven colleagues (one who was identified as an ally in the department and six who were adversarial to ESI). I emailed an interview invitation to all of the individuals. Two educators at Case A responded to the interview invitation and agreed to participate. The third educator at Case A was emailed twice but did not respond. Only one educator at Case B (the ally) responded to my invitation, the other educators were sent an initial and follow-up email. I conducted interviews with the two educators at Case A and one at Case B in November and December 2018. The educators were compensated with a $50 Amazon gift certificate. A summary of the participants is included in Chapter IV. Copies of the recruitment email and interview protocol are provided in Appendix D and E, respectively. Due to the low response rate at Case B, and the fact that both participants are faculty emeriti, a quantitative method was employed as the next phase of the case study data collection to collect more feedback from current department faculty.

Data collection: Survey

An online survey was developed to collect perspectives on institution, college, and department culture related to ESI education. The survey included modified questions from different instruments related to faculty perspectives on ESI (Bielefeldt et al., 2016), STSE (Romkey, 2015), ethical beliefs in engineering (Katz & Knight, 2017), and learning through service (Pierrakos et al., 2012). The survey was created in Qualtrics, piloted by Dr. Bielefeldt, Dr. Canney, and Dr. Swan, and revised for clarity and brevity based on their feedback.

This phase of the study targeted faculty who do and do not teach ESI to generalize the findings to the academic environment (Borrego et al., 2009). For the two case studies, I compiled the name, email address, gender, and rank for each faculty member using the respective department websites. All rostered faculty, including tenured/tenure track (T/TT), emeritus, instructors, and research professors were emailed personal invitations to complete the online survey. The respondents were invited to take the survey on February 6, 2019 (wave 1) with reminders sent to unfinished respondents on February 14 (wave 2) and 25 (wave 3). The survey closed on March 2, 2019. A copy of the recruitment email and survey (including the first question on informed consent) are included in Appendix F and G, respectively. Demographic information for the survey participants is displayed in Table 2.

Table 2: Survey participants

	Case A, % (n=15)	Case B, % (n=24)
Response rate	68	15
Wave 1	40	33
Wave 2	40	54
Wave 3	20	13
Gender		
Male	60	79
Female	40	21
Rank		
Professor	33	50
Associate professor	27	0
Assistant professor	27	25
Professor emeritus	0	13
Instructor/lecturer	0	8

There were also seven active nonrespondents, individuals who did not consent, opened the survey but did not answer any questions, or opted out of the survey (Halbesleben & Whitman, 2013) from Case B.

Data collection: Document analysis

The third method embedded in the case study methodology was document analysis. Data were collected from institution, college, and department documents available online. Document analysis describes the "systematic procedure for reviewing or evaluating documents" (Bowen, 2009, p. 27). This approach "is particularly applicable to qualitative case studies" (p. 29) because "documents can provide data on the context within which research participants operate" (p. 30). Document analysis offers a number of advantages such as availability of data sources, lack of obtrusiveness, and the exactness and coverage that written documents provide (Bowen, 2009). In addition to providing additional data that can complement interview findings and survey results, document analysis is valuable for triangulation, the "use of different data sources and methods" to "seek convergence and corroboration" (Bowen, 2009, p. 28). More detail on the documents collected is provided in Chapter V.

Data analysis

The seven interviews were transcribed verbatim with Trint and imported into Dedoose for qualitative analysis. The transcripts were analyzed with the constant comparative method, as described above for Chapter IV.

The survey data were analyzed with descriptive statistics, which is commonly employed for "quantifiable results as they pertain to opinions, attitudes, or trends" (Borrego et al, 2009, p. 54). Nonparametric statistics, medians, and mean ranks were used since the data did not meet the assumptions of a normal distribution (Gao, 2010). The Mann-Whitney U Test, a nonparametric test, was used to explore differences between responses in the two departments. This test is appropriate for a small sample size (Hinton, 2012). Statistical significance was inferred when the p-value was less than 0.10.

The documents were analyzed in accordance with the method described by Bowen (2009): "document analysis involves skimming (superficial examination), reading (thorough examination), and interpretation. This interactive process combines elements of content analysis and thematic analysis" (p. 32). The information included in the documents was organized into categories related to the research question to identity the relevant components. The next step after the initial content analysis was thematic analysis, in which the relevant parts were more closely examined. The information was coded "to uncover themes pertinent" (p. 32) to the culture at the institution, college, and department level within the academic environment of each case.

Reliability and validity

I used the framework outlined by Yin (2003), as discussed in Chapter IV, to establish reliability and validity in my case study design, which is included in Chapter V.

Although response rate is an often-cited measure of external validity in survey research, it has been criticized as a flawed indicator of generalizability (Halbesleben & Whitman, 2013). A high response rate does not equate to the representativeness of the sample but a low response rate raises questions regarding nonresponse bias (Groves, Presser, & Dipko, 2004). There are multiple factors that can contribute to a low response rate including low interest in a survey topic (Lippman, Frese, Herrmann, Scheller, & Sandholzer, 2012). This relationship can be explained by the leverage-salience theory, which postulates that different parts of a survey such as the topic, sender, and incentive have varying weights in determining if an invitee will take the survey (Groves et al., 2004). The impact of each part will depend on leverage (importance assigned by the individual) and salience (emphasis in the survey request). In considering the various aspects of the survey, "topic is particularly likely to lead to 'nonignorable' nonresponse, that which produces nonresponse error" (Groves et al., 2004, p. 3). I used the framework developed by Halbesleben and Whitman (2013) to mitigate the effect of the nonresponse bias, the "systematic difference between those who respond and those who do not respond on a substantive construct measured by a survey" (p. 915). This approach included comparing characteristics of the sample and population, analyzing responses from the different invitation waves, and benchmarking against published data. Detail on the steps I took within the framework and results from the analysis are included in Chapter V.

Another potential threat to the validity of the survey research is social desirability bias (SDB), "the pervasive tendency of individuals to present themselves in the most favorable manner relative to prevailing social norms" (King & Bruner, 2000, p. 80). This bias is especially pertinent to my work because "due to the sensitive nature of ethics research, the presence of a social desirability bias may pose an even greater threat to the validity of findings" (Randall &

Fernandes, 1991, p. 805). One approach to control the effects of SDB is to identify the conditions in which is it likely to occur (King & Bruner, 2000).

Chapter VI: Cultural Environment

The data to explore the relationship between cultural environment and ESI educational outcomes were gathered through three online surveys.

Data collection: Survey

There were two survey campaigns to learn about the ESI practices and perspectives of educators in the US, non-US Anglo, and Western Europe cultural clusters. The first campaign was part of the broader NSF study and was US-centric (Bielefeldt et al., 2018a, 2018b). The campaign included a curricular survey, which focused on ESI in courses, and a co-curricular survey, which focused on ESI instruction in activities and organizations outside of the classroom. The surveys contained the same questions but in a different order (e.g., the curricular survey began with questions on ESI in courses). The curricular survey was sent electronically to members of four American Society for Engineering Education (ASEE) divisions (Ethics, Engineering Research Methods, Community Engagement, and Liberal Education/Engineering & Society), authors of engineering ethics publications, and NSF engineering ethics grantees. The co-curricular survey was emailed to advisors and mentors of research programs (e.g., Research Experience for Undergraduates), professional societies (e.g., American Institute of Chemical Engineers), engineering service organizations (e.g., Engineering World Health), engineering design competitions (e.g., Concrete Canoe), and engineering honor societies (e.g., Tau Beta Pi). The surveys were sent to approximately 5000 faculty and staff during February to May 2016. Although the distribution process for this campaign was US-centric, it reached educators in non-

US Anglo and Western European countries via these avenues. The campaign generated responses from 1359 US, 25 non-US Anglo, and 14 Western European educators.

A second campaign was conducted July to August 2018 to collect more responses from educators in the non-US Anglo and Western Europe cluster. Dr. Bielefeldt and I compiled contacts from institutions in these clusters based on the U.S. News and World Report Best Global Universities Ranking (U.S. News & World Report, 2018). The top four to 10 institutions in each country were included (n=41 for non-US Anglo and n=75 for Western Europe). For each institution, one to three educators in each engineering and computing disciplinary unit were included. The individuals were selected based on their leadership role in the unit such as head of studies, vice dean of education, and chair. Through this process, 605 non-US Anglo and 615 Western European contacts were compiled. These individuals were emailed an invitation to complete an online survey (included in Appendix J). This survey was based on the US curricular survey but with more internationally inclusive language (e.g., graduate to post-graduate). The number of respondents and the response rate from the second campaign for each country in the non-US Anglo and Western Europe cluster are displayed in Table 3.

Table 3: Number of survey respondents from each country

Non-US Anglo	n	Response rate, %	Western Europe	n	Response rate, %
Australia	49	19	Spain	16	13
Canada	41	13	Portugal	14	16
UK	17	10	the Netherlands	13	14
New Zealand	12	17	Sweden	11	15
Ireland	5	6	Italy	10	12
			Norway	5	16
			Germany	5	5
			France	5	6
			Denmark	4	18
			Finland	3	7
			Israel	1	10
			Switzerland	1	8
			Austria	1	4
Total	124		Total	89	

Data analysis

To test the hypothesis that culture influences educational outcomes, I needed to account for confounding differences among the response groups, in both demographics and response numbers. Previous explorations of the US-dominated data from the first survey campaign found that responses differed among the curricular and co-curricular survey respondents (presumably due to intentional sampling of ethics educators for the curricular survey; Bielefeldt et al., 2016c), among engineering disciplines (Bielefeldt et al., 2016b, 2018b), and with gender (Bielefeldt et al., 2018a). Given these challenges, a matching strategy (Stuart, 2010) was used to select from among the large group of US respondents a numerically and demographically similar comparator for the non-US Anglo respondents and Western Europe respondents. For all of the US respondents who met the given criteria, a random number generator was used to select individuals for the comparator group. Separate comparator groups of US respondents were created for the non-US Anglo and Western Europe clusters due to the unique characteristics of the respondents within each cluster. Statistical tests were conducted in IBM SPSS Statistics 24 to compare the non-US Anglo to its matched sample and the Western Europe to its matched US sample. Fisher's exact tests were used to determine statistically significant differences between the samples because this test is more accurate for small sample sizes (McDonald, 2014). Statistically significant differences were noted when the two-tailed p values from the Fisher's exact test were 0.05 or lower.

The surveys across both campaigns asked respondents "Please share your thoughts about the education of engineering/computing students regarding broader impacts and ethical issues?" The open-response question was analyzed using emergent, thematic coding (Creswell, 2007) to explore patterns across the clusters.

Reliability and validity

The second survey campaign was designed to address concerns regarding generalizability due to the small sample sizes for the non-US Anglo and Western European clusters after the first survey campaign. The matching strategy was implemented to address threats to validity from confounding variables.

Reflexivity

Maxwell (2013) described that in qualitative research, the researcher is influenced by and influences the social world being studied. Reflexivity, which involves an awareness and acknowledgement of personal feelings and positions and how they affect the research process, is an important practice (Corlett & Mavin, 2019). Being the "instrument of the research" (Maxwell, 2013, p. 91), the researcher can consciously or unconsciously impact participation selection, data collection, and data analysis. As a result, researcher bias is a threat to validity. This bias cannot be eliminated but recognizing the values and assumptions that influence it can mitigate its effects.

I was motivated to pursue this research based on my personal interest in the societal and environmental impacts of engineering. I was interested in the inclusion of these topics in engineering curricula based on my limited exposure to them as an undergraduate environmental engineering student. With an engineering background, I was also particularly attuned to the role of engineering faculty in this integration of technical content and its broader implications. These experiences and predispositions cultivated an interest in ESI and belief that ethical responsibility is a foundational part of engineering.

Throughout the research process, I reflected on how bias could color my data collection and analysis. My role as an ethics researcher presumably affected my access to educators who do not teach ethics nor believe it is important. Despite efforts to interview such educators, I only successfully recruited those who currently teach or previously taught ESI. Those who do not teach or value ESI may not be inclined to respond to an interview invitation from an ethics researcher and spend their time engaging in that conversation.

Since the interviews were semi-structured, there was opportunity to introduce new questions and different probes based on my interest in a particular part of a conversation or my perception of the interviewee's interest. My age, status as a graduate student, and position as an ethics researcher may also have provided different data than would be gathered by someone else (Godfrey, 2009). During the data analysis, it was invaluable to discuss the findings and my interpretations with Dr. Bielefeldt and Dr. Knight to check if the meaning I ascribed to the data matched what they perceived as the interviewees' meaning. The member check also helped mitigate researcher bias through respondent validation (Maxwell, 2013).

Summary

The Academic Plan served as the theoretical foundation of my dissertation research. This framework informed the development of my research questions, which targeted three different components of the Academic Plan and when taken together, aimed to understand influences on engineering educations' ESI outcomes. I employed a mixed-methods design with the specific data collection and analysis methods for each chapter/article being tailored to their respective research questions. A summary of the methods is shown in Table 4.

Table 4: Summary of methods

	Ch. IV	Ch. V	Ch. VI
Research question	What individual internal influences do engineering educators identify and describe as impactful in their teaching of ESI? How are these influences manifested in the classroom through educational outcomes?	How do the academic environment and culture impact ESI practices and perspectives?	How does cultural environment affect ESI outputs?
Methodology	Case study: qualitative	Case study: mixed-methods	Survey research with quantitative and qualitative components
Methods	Engineering faculty interviews (n=9)	Engineering faculty interviews (n=7) Department faculty survey (n=39) Document analysis	US survey (n=1359) Non-US Anglo and Western Europe survey (n=124, 89)

Chapter IV: Individual Internal Influences

Influences on Educators' Practices and Perspectives Related to Engineering Ethics and Societal Impacts: A Qualitative Study

Abstract

Background: Engineering faculty play a key role in integrating technical, ethical, and societal considerations and preparing students to understand their ethical responsibility in the broader context, but educators' course planning and decision-making related to these topics has been underexplored.

Purpose/Hypothesis: The goal of this study was to identify individual internal influences that shape engineering faculty members' practices and perspectives related to ethics and societal impacts (ESI) education. The work was situated within Lattuca and Stark's (2009) Academic Plan model.

Design/Method: A case study qualitative approach was used to investigate the beliefs and experiences of engineering educators who currently teach students about ESI. Nine educators were interviewed to explore their teaching practices and the factors that shaped them.

Results: The analysis of the nine interviews revealed internal influences across four themes:, personal, academic, professional experience, and professional development. Faculty described personal influences including their interests, beliefs, and motivations. Related to the academic theme, faculty noted opportunities and deficiencies in their curricular and co-curricular experiences as undergraduate and graduate students that shaped their current ESI instruction. Professional experiences included industry, military, and international work. Professional development such as formal training and mentorship were also noted as influential on ESI practices and perspectives.

Conclusions: These findings contribute to our understanding of the factors that shape engineering educators' course planning related to ESI, which illuminates the importance of hiring faculty members with a range of experiences and providing them with the autonomy to teach ESI from a personal vantage point. The results also suggest opportunities for professional development to leverage educators' backgrounds and experiences to support the broader integration of ESI in engineering education.

Keywords: ethics, qualitative, case study, engineering faculty, societal impacts

Introduction

Understanding the social and ethical implications of engineering is important in an increasingly globalized and technology dependent world. The recently revised ABET accreditation criteria mandate that engineering programs demonstrate their graduates' attainment of "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" (criterion 3, outcome 4; Accreditation Board of Engineering and Technology [ABET], 2018). The outcome merges what were formerly distinct outcomes under ABET EC2000 "ethical and professional responsibility" and "global, economic, environmental, and societal contexts." This revision suggests the bridging of microethics, the ethical decisions of individual engineers, and macroethics, the broad responsibilities of the profession to society (Herkert, 2000, 2005), collectively termed in this research *ethics and societal impacts* (ESI). Accreditation provides an impetus for including ESI in the engineering curriculum, but decisions regarding its integration fall on individual programs and the educators within them. The literature on ESI education often focuses on examples of curricular integration, student learning, and external motivations. The role of faculty in the development and implementation of ESI instruction and the personal factors that influenced those decisions are not well synthesized in this context. Using interview data and the Academic Plan model (Lattuca & Stark, 2009), this paper examines the influence of engineering educators' personal backgrounds and beliefs on their ESI teaching practices and perspectives. Like all curriculum decisions, those regarding if and how ESI are taught are the result of an amalgam of experiences, interests, and motivations. Understanding the influences on instructional decisions can shed light on how to improve teaching efficacy; tailor professional development to motivate the broader integration of ESI in the engineering curriculum; and better support the educators who are taking on this important task. There are a number of factors internal (department, college, and institution) and external (professional societies and accrediting bodies) to the environment that also influence teaching decisions but those considerations are beyond the scope of the current study.

Theoretical Framework

Lattuca and Stark (2009) developed the *Academic Plans in Sociocultural Context* to understand influences on faculty members' course planning. This framework is a derivation of more general input-environment-output (IEO) models that have been applied in a range of contexts (Astin, 1993; Finelli et al., 2012). The Academic Plan draws from Toomb and Tierney's (1991) conceptualization of curriculum as having three components: the content, context, and form (analogous to input, environment, and output). Stark et al. (1988, 1990) demonstrated that educators' experiences, characteristics, and beliefs shape their course planning (content), their perceptions of the environment in which the course is taught (context), and the design of the course (form). The model was based on quantitative and qualitative data from faculty members who teach introductory courses in nine fields; engineering was not included. Knight and colleagues (2016) applied the Academic Plan to their study of engineering educators in Australia because the model "assumes that academics have a key role in determining strategies for teaching; their final curricular plans, however, are also influenced by a variety of forces both internal and external to their institutions" (p. 696). The Academic Plan provides examples of influences at the personal and environmental (both internal and external) levels and is intended to be a heuristic. The current study focuses on the unit level internal influences, which are defined as individual engineering educators.

Literature Review

The literature review is comprised of three sections: ESI education, challenges in ESI education, and influences on course planning and teaching.

ESI Education

Although engineering programs throughout the United States recognize and promote the value of ethical development in engineering, "there is limited empirical work on ethics education within engineering" (Hess & Fore, 2017, p. 1). The range of topics, pedagogical approaches, and objectives within engineering ethics education further dilutes consensus on which strategies and goals are most effective and important (Hess & Fore, 2017). The most recent attempt to synthesize the existing literature was conducted by Hess and Fore (2017) in a systematic review of engineering ethics interventions published between 2000 and 2015. The results illustrated the broad scope of curricular integration strategies, class formats, study rationales, learning objectives, and pedagogies associated with engineering ethics interventions. The review also examined whether philosophical ethics, case studies, and assessment strategies were included in the publications. ABET accreditation was cited as the driver for 65% of the interventions while university/school/department efforts (50%), national efforts (46%), and societal improvements were also used as justification for change.

The largest assessment of engineering students' ethical development used the Student Engineering Ethical Development (SEED) survey (Finelli et al., 2012). The instrument did not distinguish between microethics and macroethics although it appeared to emphasize microethics based on the inclusion of Fundamental of Engineering (FE) exam-style questions, which are multiple-choice and related to the code of ethics, and academic integrity issues. Despite the high quantity and quality of ethics exposure in curricular and co-curricular settings, ratings of students' ethical knowledge, reasoning, and behavior were low. This work suggests the need to improve engineering ethics education to support students' ethical development.

Challenges

There are a number of "systemic barriers to effective ethics education" (Newberry, 2004, p. 346). The crowded curriculum in engineering poses a challenge for carving out time for a required ESI-focused course (Cruz & Frey, 2003). Without an elective or required course dedicated to ESI, "it is incumbent upon the engineering community" to integrate ethics "within the context of technical courses", "which begins with self-education [and] faculty development" (Herkert, 2000, p. 311). However, this presents a challenge for engineering faculty who feel ill-equipped to teach these topics based on their own lack of training and knowledge. Haws (2001) expressed that for many engineers, "engineering ethics, at least the theoretical aspects of engineering ethics, is beyond our expertise" (p. 227). Compounding this challenge can be the lack of student engagement in ESI (Polmear et al., 2018) as evidenced when "students overwhelmingly rate the ethics component of the course as the least interesting, least useful, and the most trivial" (Newberry, 2004, p. 347). This can further discourage engineering faculty from venturing outside of their area of technical competence given the weight of student evaluations in decisions regarding retention and promotion (Ryan et al., 1980). However, Bucciarelli (2008) notes that not feeling qualified does not negate the need for teaching it. For ethics to be effectively integrated and prioritized in the curriculum, faculty engagement is essential (Colby & Sullivan, 2008).

Influences on Course Planning and Teaching

The Course Planning Exploration survey, which informed the Academic Plan, sought to understand the factors that shape faculty members' planning of their introductory courses (Stark et al., 1990). The results from 2311 respondents indicated course planning is "most strongly influenced by discipline, scholarly and pedagogical background, and beliefs about education" (p. 1). Within their backgrounds, respondents rated teaching experience (90.8%), educational purpose (83.3%), practitioner experience (80.5%), scholarly preparation (69.8%), practitioner experience (65.8%), and beliefs about teaching (69.2%) as strongly influential. Only one third of the respondents indicated that instructional workshops and formal courses were strongly influential, and religious beliefs (13.4%) and political beliefs (6.1%) were the weakest influences.

Knight and colleagues (2016) drew on archival data collected by the Australian Learning and Teaching Council Discipline Scholars for Engineering and Information and Communications Technology to study the application of the Academic Plan in the engineering context. The survey was disseminated online in 2010-2011 to all engineering faculty at 38 Australian universities and collected responses from 591 educators at 30 universities. Items on the survey were mapped to the Academic Plan to understand the influence of academics' beliefs and backgrounds on teaching. At the personal level, interest and student satisfaction were reported as significant drivers for teaching practices. The study surmised that individual and institutional considerations are important, bottom-up change can improve the educational culture, and professional development should capitalize on academics' inputs.

Katz and Knight (2017) used survey responses from 1389 engineering faculty at 31 institutions collected in 2008 to understand faculty views on ethics education. The study reported statistically significant differences between faculty members' emphasis on values and how they influence ethical decisions based on department and gender. The number of years that respondents worked in industry before and during academia was a statistically significant predictor for their belief that ethics should be taught in multiple courses. Industry experience was also positively correlated with how much faculty emphasize ethical beliefs in engineering.

Significance of this Study to the Literature

This research aims to contribute to the engineering ethics literature by exploring the role of faculty members in ESI education. It also builds on our understanding of course planning and decision-making in higher education by applying the Academic Plan to the engineering context. While the Academic Plan has been used as a framework with quantitative approaches to data collection and analysis (Katz & Knight, 2017; Knight et al., 2016), this research applies a qualitative methodology to explore the experiences and perspectives of ESI educators through their own voices.

Research Question

What individual internal influences do engineering educators identify and describe as impactful in their teaching of ESI? How are these influences manifested in the classroom through educational outcomes?

Methodology

The present study aims to understand the internal influences that are important for individual engineering educators in their course planning related to ESI. The systematic study of these factors on instructional outcomes is intended to improve ESI education by informing professional development and leveraging motivations and experiences in educators' backgrounds. Previous work has quantitatively studied the influence of diversity issues on ESI instruction (Bielefeldt et al., 2018) and demographics, discipline, and industry experience on emphasis of ethical beliefs (Katz & Knight, 2017). Although these studies provided an aggregated baseline on the relationship between personal variables and education outcomes, the existing literature does not delve into the complicated interactions between these factors and how they are influential in the words of the people who experienced them. Thus the present exploration of internal influences on educational outcomes necessitates a qualitative approach because it strives to answer questions such as "why did something occur? How does one phenomenon affect another?" (Borrego, Douglas, & Amelink, 2009, p. 56).

The present study uses a case study methodology, which involves an "in-depth study or examination of a distinct, single instance of a class of phenomena such as an… individual" (Case & Light, 2011, p. 191). Case study tests existing theory (Matusovich, Streveler, & Miller, 2010), which enables the conclusions to be generalizable to theoretical propositions (Godfrey, 2009, p. 3). As a result, it is appropriate for this application of the Academic Plan as a means of exploring the effect of internal influences on ESI educational outcomes. The cases within this research are defined as individual engineering educators who currently teach ESI to engineering students. This study employs a multi-case approach to allow for "deeper integration of, and additional context for, the individual cases" (Matusovich, Streveler, & Miller, 2010, p. 291).

Methods

Participants

Data for this study were derived from interviews with nine engineering educators who currently teach engineering students about ESI. The participants were recruited based on their participation in an online survey as part of a broader project on ESI education. Survey responses were collected in spring 2016 to understand how ESI is taught to engineering students in curricular and co-curricular settings. Information on the survey development and distribution has been published (Bielefeldt et al., 2016, 2018a, 2018b). After completing primarily Likert-type questions on the topics, teaching methods, and assessment strategies associated with their ESI instruction, respondents were asked to provide their email address if they were willing to be contracted for a follow-up interview; 230 participants provided their email addresses. Between September 2016 and April 2017, 52 individuals were contacted by for an interview and 37 interviews were completed. More detail on the interview selection process has been published (Polmear et al., 2018). From the sample of 37 interviewees, a sub-set of educators were selected to continue their participation in the broader project for an in-depth examination of their teaching practices (Bielefeldt et al., 2018c). One component of the in-depth examination was a follow-up interview with the faculty partner. Of the faculty partners interviewed for a second time as part of the in-depth examination, nine were engineering faculty. Two of those educators were excluded from the present analysis since one interview was more of a casual conversation that was not recorded and one did not include significant discussion of internal influences due to the semi-structured nature of the interview. In addition to these seven engineering educators, one participant from the first round of interviews and one colleague of a faculty partner, who was interviewed during a site visit, were included. These two educators were added to the sample since their backgrounds represented influences not included elsewhere and having diversity of participants is important to establish validity in qualitative research (Flyvberg, 2006). The nine interviewees represented eight institutions including public (n=4), private religiously affiliated (n=3), and private (n=1). The basic classification (Carnegie, n.d.) of these institutions included doctoral highest research (n=2), doctoral higher research (n=2), master's larger programs (n=3), and baccalaureate arts and science focus (n=1). The interviewees were appointed in civil and environmental engineering (n=5), engineering and physics (n=2), chemical and biological engineering (n=1), and mechanical engineering (n=1). The interviewee represented a range of backgrounds, as displayed in Table 5.

Table 5: Interview participants

Pseudonym	Gender	Rank	Bachelor's Discipline	Doctorate, Discipline	Industry Experience
Bourke*	M	Prof.	Civil Eng	Structural Eng	Design & construction
Harper	M	Assoc. prof	Chem Eng	Chem Eng	
Hopkins	M	Prof.	Eng Physics	Mech Eng	Project management, 3 years
Holt	F	Instructor	Civil Eng, Journalism	Ag/Bio Eng	Project management & consulting, > 10 years
Jardin*	F	Assist. prof	Gen Eng	Civil/Env Eng	Consulting, >10 years
Kay	M	Assist. prof	Electrical Eng	Eng Ed	Software development, 2 years
Martel*	M	Prof.	Aerospace Eng	Eng Mechanics	
Millhouse*	M	Assist. prof	Geolog Eng	Geolog Eng	
Tyler*	M	Assoc.prof	Civil Eng	Enviro Eng	

*Professional Engineer (PE)

Interviews

The in-depth (Creswell, 2007), semi-structured (Petty et al., 2012) interviews were designed to investigate influences on the educators' teaching of ESI. The interviews sought to elicit reflection and discussion related to how educators reached decisions regarding their ESI instruction and how those choices were manifested in the classroom or co-curricular setting. The specific interview prompt that led to the majority of the information in this study was, "Describe what has influenced your current efforts to educate engineering and computing students about ethical and societal issues." Various follow-up questions were sometimes asked, as well as additional questions that may have led the individual to discuss internal influences on their ESI teaching practices. The full interview protocol is included in Appendix A; due to the semi-structured nature of the interviews, not every participant was asked every question. The interviews were all conducted by the first author from March 2017 to February 2018. The interviews were 27 to 83 minutes in length with an average of 43 minutes. The seven participants who were interviewed a second time were compensated $400 for their involvement in the broader project. One of the participants received $200 since the compensation was split with the co-instructor of the course being studied. The colleague who was interviewed during the site visit was not compensated. The participant from the first round was compensated $50 for completing the one interview. The interviews were conducted in-person (n=5) or via Skype (n=4). The participants were assigned a pseudonym using a random name generator to protect their confidentiality (Given, 2008). Every interview was audio recorded and transcribed by the first author using Trint transcription software. Denaturalized transcription was used in which idiosyncratic speech elements, such as stutters and pauses were removed (Oliver, Serovich, & Mason, 2005). This method focuses on the informational content of an interview as opposed to the speech patterns between people that are emphasized in naturalized transcription including all noises and utterances. The transcripts were imported into Dedoose software for qualitative analysis.

Analysis

The interviews were analyzed using the constant comparative method (Glaser, 1965). This approach, adapted from the Grounded Theory framework, is the most common for qualitative analysis to identify themes in a data set (Leech & Onwuegbuzie, 2007). Following this method, the first author initially read through the data set: the nine interview transcripts. The data were segmented into smaller parts as a unit of analysis. Each segment was labeled with descriptive codes that were developed deductively (*a priori* and looked for in the data) and inductively (emergent in the data). Throughout the coding process, comparisons between and within the interviews were made to refine the meaning of each code and ensure that appropriate categories were developed and applied throughout the dataset (Boeije, 2002). After the first iteration, a preliminary codebook was developed that included themes of related codes. The first author then revisited all of the transcripts and modified the coding based on the codebook.

Multiple coding across researchers was employed to support reliability (Barbour, 2001). This approach cross checks codes and interpretations from multiple researchers in the study. To achieve this end, the negotiated approach was used (Garrison et al., 2006). The first, second, and third authors all reviewed two complete transcripts and collectively discussed the codes until alignment was reached. In addition to establishing agreement between multiple coders, the member check was used as a second strategy to increase reliability (Koelsch, 2013). The nine participants were emailed a preliminary schematic of the theoretical framework with variables that were discussed in the interview and coded in the analysis highlighted. A brief summary of the discussion related to each variable was provided. Questions were included in the summary and participants were given the opportunity to clarify and expand on the interview. Participants were also offered the full transcript for their reference. All nine of the participants reviewed and approved the member check. An example member check is included in Appendix B.

Results

After analyzing the nine interview transcripts, four themes related to internal influences were identified: Personal, Academic, Professional Experience, and Professional Development. The following results are presented by theme.

Personal

The theme was split into five codes that described intrinsic and personal influences on educators' ESI practices and perspectives, displayed in Table 6. In the table, the definition column shows the description used to apply the code to the interview segments, "n" indicates the number of interviewees who discussed the code, and the source indicates if the code was developed *a priori* based on the literature or was emergent from the data set.

Table 6: Codes related to the personal theme

Code	Definition	n	Source
Motivation	Goals, desired outcomes related to ESI instruction, what the educator hopes the students get out of their teaching, and reasons for specific approaches	8	Emergent
Beliefs	Personal convictions that drive what and how ESI-related topics are taught, including beliefs related to the meaning of ESI, the way ESI should be taught, the role of an educator, and the role of engineers in society	7	Lattuca & Stark, 2009
Interests	Personal interest in ESI-related topics influenced the educators to integrate those topics into their courses	5	Emergent
Faith	Religious views/convictions influenced perspectives and/or practices related to ESI	1	Lattuca & Stark, 2009
Family	Educator's own role in their family or their family members influenced their perspectives and/or practices related to ESI	1	Emergent

Motivation was discussed by eight of the interviewees. The educators described the motivation driving their efforts to teach ESI related to (1) increasing student engagement, (2) developing ethical behavior, (3) fostering students' awareness of ESI in the human context, (4) preparing students' for professional careers, and/or (5) providing instructional models for how to integrate social and technical issues.

Student interest is an important driver of motivation (Vanasupa et al., 2009) and can depend on both interest in the course itself and the material presented within it. Dr. Martel, who developed and teaches a course on ethical and social issues in engineering, strives to capture students' engagement "by making the classroom an inviting and interesting place and… trying to make the material relevant to their lives." This motivation influenced his education outcomes including his teaching methods.

> …things I tend to try are to both put things like ethical theories or other sort of abstract ideas and concepts and material that we cover into terms that they can relate to using examples that are current that that they might have some opinions about and… as much as I can play off their own personal experiences…some of the bigger picture questions about technology and society… use examples or cases that they can relate to that within which are embedded, you know, more fundamental questions that they can apply more broadly than those specific examples.

One challenge in ethics education is attaining higher levels of learning and developing ethical knowledge, reasoning, and behavior (Finelli et al., 2012). Two of the interviewees expressed the motivation behind their ESI instruction is supporting students' ethical behavior. Dr. Kay, who teaches a required professional issues and ethics course, described how he designed his course with the goal "to increase the likelihood that there will be a transformative moment… that actually affects their ethical behavior." The desired outcome of the course was facilitating this moment for students, which could support their ability to navigate ethical dilemmas in their futures instead of focusing on content knowledge related to the code of ethics. Dr. Hopkins, who teaches a required introductory engineering course, similarly discussed his motivation to bridge ethics instruction in the classroom and ethical behavior outside of it. He wanted "to bring the thinking of engineering ethics into their day-to-day experience both as a student and apply immediately upon graduation." This motivation stemmed in part from noticing a disconnection in the past in which students performed well on the ESI content and provided the correct answers but displayed unethical behavior such as downloading homework solutions from the Internet.

Dr. Holt and Dr. Millhouse, who both teach ESI via experiential design and community engagement, described their motivation as fostering students' awareness of ESI in the human context. The technical and social considerations in engineering can be disjointed in the curriculum and Dr. Holt sought to develop a course that merged the two. At her institution, service courses without a technical foundation taught by non-engineers and engineering courses without social context did a disservice to students so her course "hit a little void between those two, it filled that gap in for people who wanted a little understanding of each kind." This course was motivated to expose students to the human dimension of engineering since "humanization is really one of the big things that would be significant to make engineering… an ethical… discipline."

The fourth motivation described in the interviews was preparing students for their careers as professionals. Dr. Jardin, who teaches environmental engineering senior design, integrated ESI with an unexpected scenario that modeled an ethical dilemma embedded in the students' senior design projects; students did not know the dilemma was fictional. The motivation behind teaching ESI in this way was having an "open-ended and realistic…opportunity for the students to really kind of flex their ethical muscles…to help them prepare for their future lives as professionals."

The fifth motivation identified in developing and implementing ESI efforts was providing an example for how to integrate these topics into technical engineering courses. Dr. Harper, who developed and teaches sustainability courses, described his motivation for creating an educational intervention in which students researched and discussed the social, technical, political, economic, and environmental sides of hydraulic fracturing.

> And I'm hoping… that this… can be demonstrated as an easy way to integrate these contemporary issues, sustainability, and arguably ethics or empathy in engineering in a common engineering course without completely derailing the syllabus. You can still cover pump sizing at the same time as having people think about the impacts of fracking.

These results reinforce the importance of intrinsic motivation on course planning and decision-making (Knight et al., 2016). The interviews also underscored that educators approach ESI with different purposes and intentions that result in varying instructional practices.

Personal beliefs were discussed by seven of the interviewees. This broad code included two primary sub-themes: (1) beliefs about the meaning of ESI and (2) the way it should be taught.

ESI is inclusive of a range of topics that harbor different meaning based on an individual's perspective and positionality. Dr. Kay infuses his identity research into the professionalism and ethics course that he teaches to engineering students in their last year. The way he conceptualizes ethics informs how he teaches it.

> So to me, ethics is all about… identity…So I mean, I would hear people… like 'how can we talk about this?' And that was such a foreign question because my, so much of my core life is thinking about what is right and what is the path of doing what's right and what is wrong…

His belief that unethical behavior stems from students' personal feelings and internal tensions motivated him to encourage students to reframe those emotions and reconcile their personal and professional identities so that they can ethically navigate their future careers. Dr. Tyler, who teaches a professional issues course for civil and electrical engineering students in their last year, described ethics as "one of those most important beliefs that you hold most strongly." His values-based conception of ethics includes being "an honorable person" who "believe[s] in fairness and justice for everybody."

Three interviewees described macroethical interpretations of ethics as the intersection of engineering and an engineer's responsibility to society. Dr. Millhouse's involvement in EWB as a faculty advisor was driven by his beliefs that "as somebody that has the ability to give back" he "always felt drawn to the idea of being able to give back and help those people that are less fortunate than ourselves." Similarly, Dr. Harper described that "idealistically, I would see engineers and scientists working… to collectively solve problems for the benefit of society." This belief shapes his responsibility as an educator and his instruction related to ESI.

> I feel professionally obliged to push towards that ideal embodiment of scientists and engineers and to the extent I can, to ingrain that way of thinking into students so that regardless of their career trajectories they keep in mind the ideal nature of the engineering profession.

Dr. Holt described her interpretation of ESI in experiential design as "recognizing the relationship between engineering and humankind." Despite some faculty labeling ethics and societal context "as a soft skill", she explained, "the most technical skill is to be able to know what's right to do when." These results suggest that there are a number of entry points into the discussion on ESI in engineering. Educators can leverage their own understanding of ESI and take a personal approach that supports their connection to the material while increasing its relevance to students.

Educators also described their beliefs on how ethics should be taught to engineering students as influential on their personal practices. Dr. Bourke, who is the chair of a civil engineering department that teaches ethics across-the-curriculum, explained how he

> …never saw a disconnect between engineering and ethics and always felt that when you're teaching specifically design courses, most importantly design courses, that ethical considerations have to be integrated in the class… And so I think ethics needs to be integrated throughout the curriculum. And I've always felt [that]; it's not something I've come across recently.

As a result, he teaches ethics in steel design and his department integrates ESI content and assessment in a host of technical courses including foundation design, reinforced concrete design, and water treatment design. Similarly, Dr. Harper stated, "colleges of engineering at large ought to have some explicit goals or strategic integration of values into engineering education to indeed encourage the integration of teaching to the affective domain in addition to the cognitive domain." Although his institution is still building momentum toward this integration, it has long been established in his own courses. Dr. Harper integrates political, social, and environmental impacts of contemporary issues in technical courses to bridge the cognitive domain with the development of empathy and ethical awareness.

Dr. Martel expressed that another consideration in ESI education is not just where it is taught but how it is framed. In addition to teaching a course dedicated to ethical and social issues in engineering, Dr. Martel integrates these topics into his junior-level mechanical engineering design course. Instead of treating ethics case studies and discussions of societal impacts as a "bolt-on" to the end of the course after projects are complete, he and his co-instructor "treat it as if this is part of the class. It's important." Based on his understanding of teaching for immediacy, Dr. Martel expressed that students are

> …very perceptive about those clues and so if you don't think a topic is important, you say you think it's important they can they can spot a lie and so I'm a big proponent of teachers

> using all the tools in their arsenal to convey to the students both verbally, nonverbally through your behaviors and attitudes that the material that you're teaching is important.

This comment relates to the hidden curriculum in education in which students learn through tacit messages in addition to formal lessons (Hafferty, 1998; Hafferty & Gaufberg, 2017; Margolis, 2001).

Personal interests were identified as influential in ESI teaching for five of the interviewees. When asked to describe what has influenced his current efforts to educate engineering students about ESI, Dr. Martel responded “I've never been probably what you'd call a typical engineer maybe. I have a pretty eclectic set of interests.” His “diverse set of interests” includes “philosophy… history, literature, [and] sociology.” His research and instruction on ethical and social issues stemmed from his desire to “find some way to combine all that with my engineering.” ESI is the thread that ties together his broad range of interests.

Dr. Kay explained that although identity may be a unique lens through which to view ethics, it enables him to bring his research interest into the classroom.

> I can see how someone else would approach it from a different vantage point… But I have things to contribute to ethics education from my psychological research… on identity and I want to teach from the place that I'm connected to.

Dr. Harper infuses his personal interests in sustainability, social justice, and environmental justice into his engineering courses through the discussion of contemporary issues. Dr. Tyler connects his ESI instruction to his own interest in military leadership and uses General Collin Powell’s 18 Principles to provide teachable moments for students. Dr. Holt connects her first-year and design courses to her interest in international development and rural communities.

Faith was identified as an influence by one of the interviewees. Dr. Kay teaches at a religiously affiliated institution where the faculty members are not "precluded from infusing our faith in the scholarship." He teaches ethics and professional issues on "the assumption of two worldviews… One that we're talking about engineering things… And two, at our university, I'm going to speak from the Christian worldview." Although religious beliefs were cited as one of the weakest influences in the work that informed the Academic Plan (Stark et al., 1990), the qualitative findings suggest that such influences might not apply for the majority of educators, but they can be highly impactful for some.

Family was cited as influential by one interviewee. Dr. Holt came "from a family of engineers" and "having that exposure through my own family… that's what drove me towards it." Dr. Holt pursued engineering as a second career based on her exposure to the impact of engineering through her family while her role within her family prepared her to teach experiential design. She described one of "the two things I think make it easiest for me to teach these courses… my experience as a mom." She described that her experience as a mother showed

> The need for compassion and empathy is essential to create a common understanding, and this is something often lost of the classroom. By employing empathy with students, as well as encouraging students to use empathy themselves, service learning becomes less of a chore and more of a mission.

Dr. Holt's role in her family shaped her approach to ESI education through the transformative power of empathy, which has been explored to facilitate perspective-taking and ethical development in engineering education (Hess, Strobel, & Brightman, 2017).

Academic

The academic theme was split into two codes: interviewee's own education and international experience as an undergraduate or graduate student, shown in Table 7.

Table 7: Codes related to academic theme

Code	Description	n	Source
Own Education	The formal education, instruction, training received as an undergraduate or graduate student in the curriculum helped shape perspectives and/or practices related to ESI	6	Lattuca & Stark, 2009
International Service	Service experience abroad through Engineers Without Borders (EWB) as a student influenced the educators' perspectives and/or practices related to ESI	1	Emergent

Six of the interviewees discussed their <u>own education</u> as an influence on their understanding and teaching of ESI in engineering. There were a number of nuances within this broad code including interdisciplinary courses that interviewees took related to ESI, lack of relevant coursework, and perceived deficiencies in their own training that motivated the intentional integration of ESI in their teaching.

Dr. Martel described his ethical and social issues course as the confluence of his engineering and non-engineering interests, which were cultivated during his own education.

> [When] I was in college as an undergraduate, I used all of the few electives I had as engineering student on philosophy classes… And so I've always had an interest in philosophy and in fact I briefly at the time I finished my Master's degree toyed with the idea of getting a Ph.D. in philosophy as opposed to engineering.

Taking courses outside of engineering exposed Dr. Martel to the considerations of ESI from a philosophical perspective, which ultimately informed his teaching as a way to bridge the technical side of engineering and the ethical considerations embedded within it.

Other interviewees described the dearth of formal exposure to ESI they encountered in their own education. Dr. Tyler, who teaches at his alma mater, reflected on the changes at the institution from his time as an undergraduate to professor.

> I'm so thankful that it's part of curriculum now, it wasn't when I was a student back in the stone ages. It wasn't, we had no ethics class, we had nobody that ever came to us and talked about professional life or how do you create a positive reputation. I kind of see it as one of the reasons I'm here. Something that fits, it fits, I feel comfortable with it and I think the students grab on.

From his perspective, the campus-wide ethics requirement is a welcome addition. Despite not having formal exposure to ethics and professionalism while he was a student, the integration of these considerations into the curriculum drew him to teaching at an institution and in a department that reflected these values he shared. Dr. Millhouse, who teaches ESI via EWB, noted, “my training has been limited to classes I've taken in school as far as engineering ethics and I took a sustainability class.” Although not a significant portion of his education, the ethics and sustainability courses provided his only formal exposure to ESI.

Dr. Holt, an instructor in contextual and experiential design, was motivated to teach these courses by the perceived disconnection between academic material and its practical application that she encountered as an engineering student.

> I know when I was a student a lot of the material that we'd be going through… the applicability was problems out of a book. I never really got a strong sense of where I would be using this as a professional and… it sort of put a glass between me and my responsibility to the client or the beneficiary or whatever you want to call them

> depending on the application, the employer. So there's always that little separation that I think acts as an insulator on your own ethics to some degree.

Dr. Holt returned to her alma mater to develop and teach courses that fused topics that appeared disparate during her own training. The application and humanization of engineering connects students to their ethical responsibility.

International service as a student was also cited as an influence on ESI practices and perspectives by one of the interviewees. Dr. Millhouse participated in EWB as a graduate student, which motivated his involvement as a faculty advisor. He described the experience as transformational since it shaped his perspective on engineering and his role in propagating this experience to other students.

> So once I was exposed to that, it kind of changed my perception and I just always felt drawn to wanting to try to do something more than just, you know, writing another paper or trying to get another grant. It seemed like if I could get students involved and have them kind of experience that as well, it can really make a difference on their lives and also the lives of those people we're actually assisting.

Participating in EWB as a student, traveling to the community, and witnessing the need for, and impact of, engineering motivated Dr. Millhouse to get involved with EWB during his second semester as a faculty member. Dr. Millhouse said "as far as an ethical perspective, the way I think about EWB is, it basically is the only thing that I think I do well here as far as teaching ethics in engineering."

Professional Experience

In the present study, internal influences include experiences prior to the educators' current role (professor or instructor in higher education) in their current department. Engineering faculty may bring a host of non-academic professional experiences to their teaching, which can be influential in shaping their practices and perspectives related to ESI. These codes are shown in Table 8.

Table 8: Codes related to professional experience theme

Code	Definition	n	Source
Industry	Professional experience in industry was influential in shaping practices and/or perspectives related to ESI education	2	Knight et al., 2016
International work/experience	Service or professional work outside of the US influenced ESI teaching practices and/or perspectives	1	Emergent
Military	Military experience was influential in shaping practices and/or perspectives related to ESI education	1	Emergent

Two interviewees mentioned their time in industry as influential, without being prompted to consider that experience. Another three of the interviewees had industry experience but did not discuss it when asked to reflect on what was influential in their ESI teaching. When asked about the influences on her current efforts to educate students about ESI in environment engineering senior design, Dr. Jardin cited her "ten years of professional experience." Her work as a professional engineer informed her perspective that her "role in senior design is to help students transition from being students to being professionals." As a result of her experience in industry and her responsibility to prepare students for their own careers, she liked to "to bring in a lot of not just professional level project experience [but also] open-ended problems" including ethical dilemmas without a clear solution.

Dr. Holt described the influence of her professional background since one of the things that "make it easiest for me to teach these courses [is] my experience in practical applications." Dr. Holt reflected that some of the professors she studied under as an undergraduate, and work with now, were unable to connect academic and industry applications of engineering and her work in consulting helped bridge that gap. Contextualizing course material helped students understand their ethical responsibility since problems were framed in terms of clients and communities instead of textbook calculations.

Beyond her experience in industry, Dr. Holt described her international experience as a working engineer as impactful. Dr. Holt was the only interviewee who discussed this influence.

> So before I came here I was, I got pretty involved in the water industry associations… participating [ ] led to traveling and then the more I traveled the more I realized that that knowledge was being misappropriated essentially internationally … volunteers… weren't really challenged to think about why they were doing what they were doing or how they were doing it, who they were doing it for. So [they] would just sort of do what they already were doing in a different place, which is the recipe for failure.

Based on her experience abroad, Dr. Holt developed an understanding for how engineering in developing communities can be improved, ideas she implemented in her experiential design course that centered on building a water project in Central America. While working with EWB as a consulting engineer, Dr. Holt witnessed the ways in which students' preparation for such work could be improved.

> Students tend to kind of do the traditional engineering international development which is… look at … a textbook to figure out how to do the design and plunge forward. Essentially impose it on the recipient…we were observing these students trying to find their way through a mess… and we're saying 'if only we were able to teach our students to think about this before they start focusing on the engineering.'

This realization and conversation with her future co-instructor led to the development of her course as a way to prepare students to look beyond the technical considerations and think of the recipient. Her international experience provided a motivation and framework for teaching students about engineering design and an arsenal of stories on which to draw.

> So I'll tell stories about my experiences internationally. They'll tell stories about kind of their growing awareness… we talk about the times that we were there and we witnessed a man beating his wife or we talked about the time that we were working with the community and one member of the community came crying to us because her child was hungry and she was out of water while the neighbor was pulling their water, things like that.

Dr. Tyler, who served in the military for 27 years, explained the impact of his service on his teaching. Dr. Tyler was the only interviewee who served in the military.

> I do use my military experiences to drive home a point… We talk about safety all the time, the ethics associated with safety. I lost a soldier as a young officer to safety related accident, I've never forgotten it…You walk around with that burden that you didn't send somebody home who should have gone home… as a project manager on a project and one of your workers gets electrocuted on a job site, you know, you're going to live with that for the rest of your life. So we try to tell them those kinds of things.

This internal influence affected his educational outcomes through the importance he places on ESI and the way he teaches it.

Professional Development

There were four codes identified within the professional development theme, as shown in Table 9. These codes are more explicitly connected to the educators' teaching as opposed to the more personal themes presented above.

Table 9: Codes related to professional development theme

Code	Definition	n	Source
Formal training/ professional development (PD)	Participation in workshops, seminars, conferences that supported ESI instruction; could be described as the presence or absence of PD opportunities	3	Lattuca & Stark, 2009
Community of support	Group of people with similar interests, goals, priorities enabled or encouraged ESI teaching, engagement with group outside of home institution	3	Emergent
Change in teaching/research interest	Academic interest shifted and influenced new direction in instruction or career	3	Emergent
Mentor	Academic or professional mentor was influential	2	Emergent

Three of the interviewees described their participation in formal training and professional development as influential to their ESI-related educational outcomes. Dr. Harper explained the influence of professional development opportunities on his ESI teaching.

> The National Effective Teaching Institute [NETI] [and] my attendance / participation in that organization was kind of a catalyst. I probably had these ideas brewing but realized that other individuals were professionally engaged…my professional engagement in these activities finally found traction after visiting those professional development events.

Dr. Martel "started participating in conferences of organizations like Society for Philosophy and Technology and IEEE [Institute of Electrical and Electronics Engineers] and ASME [American Society of Mechanical Engineers]" as a way to learn more about combining his non-engineering interests with engineering via social and ethical issues. Dr. Jardin developed her ethics instruction, a curveball dilemma integrated into students' senior design projects, based on a presentation she attended at an American Society for Engineering Education (ASEE) conference.

> I'm sure I meant to take better notes, but the note that survived was "ethical curveball dash senior design". So from that note I said "well let's just make it what I feel like it

should be." … I just, you know, took this idea ethical curveball but I do remember sitting in the seminar and my mind wandering to how would I do this kind of thing in senior design.

These professional development opportunities provided ideas for integrating ESI into engineering, connections with people who share similar interests, and the confidence to translate interests into instruction.

Three of the interviewees cited a community of support built during their professional development as influential to their ESI practices and perspectives. Since ESI may appear on the periphery of engineering to some faculty, related research and instruction can feel marginalized (Polmear et al., 2018). As a result, finding other faculty committed to ESI can bolster individual efforts and legitimize the broad pursuit. Dr. Harper described that through NETI and ASEE, he "found a tribe of sorts of individuals that had similar interests and that was very encouraging and reinforcing to me." Dr. Kay also explained that his participation "in a broader community that's outside of [his institution]… really informs my picture of ethics and engineering education."

Three of the interviewees discussed a pivot in their careers that occurred before their current position and how this change in teaching/research interest shaped their ESI practices and perspectives. As a new area of research and scholarship, Dr. Harper described "the integration of contemporary issues like social justice, environmental justice into engineering education" as "a completely humiliating and humbling experience reading these new texts and papers and learning a new vocabulary and trying to practice that." Although venturing outside of his chemical engineering expertise was daunting, Dr. Harper was enthusiastic. Motivated by environmental factors, such as tenure and support from the department head and college dean, he developed his intrinsic interest into ESI educational outcomes.

Dr. Martel's career followed a similar trajectory in that tenure and institutional pressure to increase research activities motivated him to change the focus of his research and scholarship. This code within the professional development theme also speaks to the interaction and interconnectivity of internal and environmental influences.

Two of the interviewees described mentors during their own education as influential on their ESI practices and perspectives. Currently serving as an advisor for EWB, Dr. Millhouse learned from those who had that role when he was a student in EWB. When asked about his formal training related to ESI, Dr. Millhouse described mentorship as the most impactful experience.

> The mentors I've had, like the people I worked under as a student when I was first in Engineers Without Borders. I drew a lot from working with them and [ ] understanding how they interact with society… how they treat people. The ethical kind of ideas they bring as far as the engineering we do for other people so I would say probably more from the mentor-mentee role than any like formal training.

Limitations

With an average of 43 minutes for each interview, it was impossible to capture the complexity of the lived experiences of the participants and how it informed their practices and perspectives related to ESI. Qualitative studies with a small number of participants are also limited in terms of external validity and generalizability. However, the aim was not to generalize the importance or influence of particular codes to all engineering educators but to analyze educators' perspectives and experiences within the Academic Plan, which has the potential to explain and catalyze exploration of similar questions for other educators.

Another limitation of this research is the lack of racial diversity represented since all of the interviewees were White. All of the interviewees were educated in the United States and currently teach in the United States so generalizability is limited beyond this national context. Although the interviewees had degrees in a range of disciplines, not all disciplines were represented. Future work could broaden the recruitment of participants to explore these factors.

The Academic Plan serves as a schematic and heuristic for evidence-based influences on teaching decisions. However, like any model, it simplifies the reality of a complex phenomenon. The boundaries between the internal, external, and environmental influences are more blurred than they appear in the model. Interactions between the factors lend to the richness of the story but can be challenging to compartmentalize. The spatial and temporal boundaries of the influences can also be difficult to ascertain. The member check was intended to mitigate some of these limitations.

Conclusions

This study used the Academic Plan as a framework for exploring the factors that influence engineering educators' practices and perspectives related to ESI education. The Academic Plan provides a model for conceptualizing course planning in a sociocultural context. The model connects external influences, internal influences, educational environment, educational process, and educational outcomes. This research focused on internal influences at the level of individual engineering educators. Based on interview data with nine engineering educators, a derivative of the Academic Plan was developed, as shown in Figure 2.

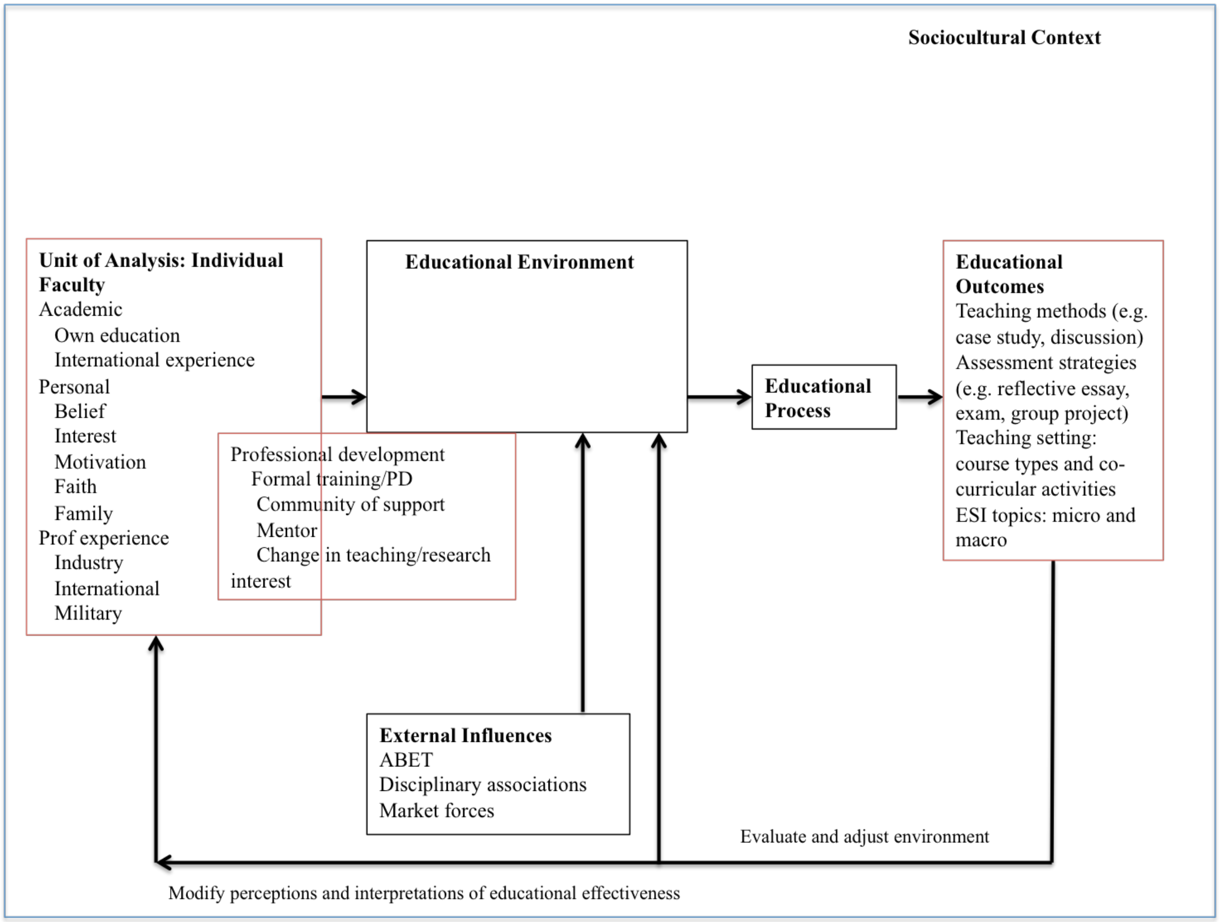

Figure 2: Internal individual influences on ESI teaching practices among engineering faculty: Derivative of the Academic Plan

This model provides more granularity at the level of individual internal influences based on academic, personal, and professional factors that were identified and discussed as impactful. The model expands on previous work by including specific variables of interest in the context of engineering ESI education with focus on the "unit of analysis: individual faculty" and "educational outcomes" boxes. The model demonstrates the connection between the individual educators, the environment in which they teach, the process of course planning, and the resulting outcomes. Educators bring characteristics, beliefs, and experiences into the academic environment. The environment is shaped by internal and external forces that feed into the process through which curriculum is designed. Through this process, educators develop specific outcomes including decisions related to teaching methods, assessment strategies, instructional settings, and ESI topics. Professional development can also leverage interests and motivations and provide a way to bridge these internal influences and educational outcomes. The model also shows that course planning is an iterative process that includes input from students and internal and external evaluations on effectiveness. This research deconstructed the Academic Plan to focus on influences at the level of individual ESI educators but future work could explore the interactions between pieces of the framework since reality is not as neatly compartmentalized.

Implications

Developing in parallel with the national conversation regarding the integration of ESI in engineering is the consideration of how to motivate engineering faculty to implement the external mandate. Top-down approaches from industry advisory boards, accreditation bodies, and professional associations provide an important driver. However, intrinsic motivation can be a more powerful lever (Knight et al., 2016). The results of this study reinforce the importance of internal influences on education outcomes.

The results also suggest the importance of hiring faculty with a broad range of perspectives and experiences. Engineers with industry, military, and international experience provide different lenses through which to view ESI and offer varying approaches to integrating those topics into their courses. Since “engineering is a profession of practice”, it is important for engineering faculty to “have relevant practical experience” (American Society of Civil Engineers [ASCE], 2018, p. 39). Having both research and practitioner experience also better qualifies engineering faculty for teaching knowledge, skills, and attitudes deemed important for engineering practice (Estes & Welch, 2006).

The qualitative analysis illuminated the value of providing engineering faculty with the autonomy to teach ESI from a personal vantage point. Although engineering educators can feel unprepared or ill-equipped to teach social and ethical issues, there are many ways to enter the conversation that do not require formal training in philosophy. Faculty should be encouraged to leverage their background and find a way to connect engineering and ESI. This strategy can elucidate the interconnectivity of technical, societal, and ethical considerations for students thus improving its relevance and value.

This work aimed to support the integration of ESI by situating the findings in a framework for the influences on educators' teaching practices, which can be leveraged to tailor professional development. Fostering a sense of ethical responsibility and societal context in the next generation of engineers requires the current generation of engineering faculty to feel prepared and comfortable integrating ESI into their courses.

Chapter V: Department Culture

Impact of Academic Environment on Faculty's Ethics Teaching Practices and Perspectives: Case Study of Two Engineering Departments

Abstract

This research employed a case study methodology to explore the impact of academic environment and culture on faculty teaching practices with respect to ethics education, inclusive of microethics and macroethics. Framed by the Academic Plan model (Lattuca & Stark, 2009), this research aimed to understand how environmental forces at the institution, college, and department levels shape individual faculty member's instruction and perspectives related to ethics and societal impacts (ESI). Two engineering departments (each at a different institution) were included in the study: chemical and biological engineering, serving as Case A, and electrical and computer engineering, serving as Case B. The two cases were selected to represent cultures related to ESI education that appeared divergent in initial faculty interviews but shared similar broad institutional characteristics. Engineering educators' perspectives on the importance of ESI, the department, college, and institution culture, and their personal instructional practices were gathered via semi-structured interviews and online surveys. Data were also collected from publicly available documents such as mission statements, program outcomes, degree plans, and general education requirements to understand the inclusion of ESI in the formal curriculum and institutional identity. The results indicated that the educators in both cases valued the importance of ESI in engineering education. The data also suggested the influence that culture and leadership, especially at the department level, exert on perceptions of support for ESI instruction. Based on document analysis, no large differences were apparent at the institutional or college levels. The case study research was motivated to elucidate the relationship between academic environment and ESI education to better support the integration of ESI in the engineering curriculum and foster cultures that support faculty members' teaching practices on these important issues.

Keywords: engineering ethics, societal impacts, mixed-methods, case study

Introduction

The education on ethics and societal impacts (ESI) in engineering curricula has gained momentum over the past couple of decades (National Academy of Engineering [NAE], 2016). ESI encapsulates microethics, the duties and decisions of individual engineers, and macroethics, the responsibilities of the engineering profession to society (Herkert, 2005). Forces such as the Accreditation Board of Engineering and Technology (ABET, 2018), National Science Foundation (NSF, 2018), National Academy of Engineering (NAE, 2017), and American Society for Engineering Education (ASEE, 1999) have been important advocates for the ESI education and professional preparation of the next generation of engineers. As technology continues to develop at an unprecedented rate, engineers will be tasked with the design and implementation of systems whose social and ethical implications are not yet understood. Emerging technologies and the ever-expanding reach of engineering put additional responsibility on engineering programs to instill in their students an understanding of ethical responsibility and broader context (ABET, 2018). However, institutions, programs, and educators have considerable autonomy in how they meet accreditation requirements. Engineering educators play a particularly important role in ESI education since they have the greatest access to engineering students in the curriculum, can bridge technical content and its ESI implications, and lend relevance to the importance of ESI in the engineering profession. Faculty's educational outcomes, including their perceptions of the importance of ESI and their instructional practices related to it, are the confluence of a range of interrelated influences that operate at various levels. Using the Academic Plan model (Lattuca & Stark, 2009) and case study methodology, this research seeks to understand how influences at the institution, college of engineering, and engineering department levels affect the culture experienced by engineering faculty and it turn, impact their ESI teaching outcomes.

Theoretical Framework

The theoretical framework underpinning this research is the *Academic Plan in the Sociocultural Context* (Lattuca & Stark, 2009). This model was developed to conceptualize course planning and curriculum development in higher education. The Academic Plan was developed based on interviews (Stark et al., 1988) and survey responses (Stark et al., 1990) from faculty who teach introductory courses in nine fields, which did not include engineering. The model posits that external influences (e.g., government policies and accrediting agencies), internal influences (at the level of the institution and individual), and educational environment affect educational outcomes. The Academic Plan is a derivative of the input-environment-output (IEO) model: the components being analogous to the personal internal influences, educational environment, and educational outcomes, respectively.

The present study focuses on the influences of environment related to the institution, college, and department (termed the 'internal influence' at the institutional and unit level by Lattuca and Stark) and how they shape the ESI educational outcomes of faculty in terms of ESI teaching practices and perspectives. Institutional forces such as the "college mission, financial resources, and governance arrangements, can have strong influences on curricula" (Lattuca & Stark, 2009, p. 13). Pertinent department-level influences include faculty perspectives on teaching, program goals, available resources, and student characteristics. It is important to consider influences at these two levels in conjunction since "discussing institutional and unit-level influences separately is…artificial. It is the interaction among different influences that creates a particular educational environment in which curriculum decisions are made" (Lattuca & Stark, 2009, p. 66). External influences and personal influences on individual faculty members are beyond the scope of this research.

Background

The background is organized into three sections: ESI in higher education, ESI in engineering education, and ESI education by engineering discipline. This structure represents the multiple levels at which environment can influence ESI education through faculty course planning.

ESI in Higher Education

Ethical reasoning is identified as one of the essential learning outcomes for undergraduate students (American Association of Colleges and Universities [AAC&U], 2009). The AAC&U developed the VALUE rubrics for each learning outcome as a national "framework of expectations" for assessment at the institutional-level. The rubric for ethical reasoning includes "ethical self-awareness", "understanding of different ethical perspectives/concepts", "ethical issue recognition", "application of ethical perspectives/concepts", and "evaluation of different ethical perspectives/concepts." Across all institution types, undergraduate students are expected to develop in their ethical reasoning as part of a liberal education. One way for institutions to develop ethical reasoning is through its inclusion in general education requirements (Warner & Koeppel, 2009). Although recent decades have seen general education being separated from ethics and morality (Reuben, 1996), these requirements can expose students to ESI-related topics, such as global perspectives, technology and society studies, philosophical ethics, and sustainability, outside of the engineering program. Despite this national directive, the degree to which ESI is included can vary by institution type. For example, the frequency that a course assignment required students to discuss "ethical or moral implications" was higher for faculty at Catholic four-year colleges and other religious four-year colleges than faculty at public four-year college and private nonsectarian four-year colleges (Stolzenberg et al., 2019).

At the institutional level, "missions are an important influence on curriculum" (Lattuca & Stark, 2009, p. 69). A mission statement serves as a symbolic and practical embodiment of an institution's core values and strategic planning. Although there is debate on the value of mission statements from the "requisite first step on the road to organizational success" to "rhetorical pyrotechnics- pretty to look at…but of little structural consequence" (Morphew & Hartley, 2006, p. 456), they have become ubiquitous in higher education. This study includes mission statements in the document analysis since they serve "as an artifact of a broader institutional discussion about its purpose" (Morphew & Hartley, 2006, p. 457). Mission statements "have an important influence on goal congruence between the organization and its employees" (Palmer & Short, 2008, p. 454), which can have implications for accreditation, accountability, and identity. However, within the same institutions, colleges can develop unique ethical climates (Malički et al., 2019) and engineering departments are generally located in colleges separate from philosophy (such as College of Arts and Sciences) where ethics education was historically focused.

ESI in Engineering Education

A "culture of disengagement" has been described in engineering in which students' perception of their professional/ethical responsibility and understanding of the implications of technology decline longitudinally (Cech, 2014).

> Despite institutional enthusiasm for nurturing aspiring engineers' engagement with questions of public welfare, the restructuring of accreditation, and a broad recognition that such engagement is important to the role of engineers, engineering education fosters a culture of disengagement that defines public welfare concerns as tangential to what it means to practice engineering (p. 45).

Engineers, like all professionals, "provide a worthwhile service in the pursuit of important human and social ends…[and] work within ever-increasing complexity and changing conditions" (Sheppard et al., 2008, p. 4). The nature of engineering and the socio-technical context in which it is embedded necessitates ethical responsibility in the profession. The undergraduate curriculum plays a key role in developing an understanding of ESI "because formal engineering education may be the only institutionalized training where future engineers learn ethics and the responsibilities of their profession" (NAE, 2017, p. 7). Practicing engineers have reported encountering ethical issues in their work; feeling unprepared to address such challenges; and feeling that engineering students should be exposed to ethics in their academic training (McGinn, 2003). Another motivator for the integration of ESI in engineering education is accreditation. ABET mandates that accredited programs demonstrate their students' "ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economics, environmental, and societal contexts" (criterion 3, outcome 4; ABET, 2018). Although external forces such as NAE, industry, and ABET recognize the importance of ESI, there appears to be a misalignment between the expectations of the profession and realities of the curriculum (McGinn, 2003; Sheppard et al., 2008).

Engineering programs have considerable autonomy over decisions regarding where and how ESI is integrated into the curriculum. There is a wide range of learning objectives, integration strategies, and pedagogical approaches associated with ESI in engineering programs across the United States (US). Despite the "tremendous variation in the kind, amount, and intentionality of coverage of ethical issues" (Colby & Sullivan, 2008, p. 332), many programs build from a similar foundation. Common curricular integration strategies include a required course in ethics, ethics integrated across-the-curriculum, and a module in engineering science or design courses (Colby & Sullivan, 2008; Herkert, 2000; Hess & Fore 2017). Dominant pedagogical trends include ethical frameworks such as codes of ethics and moral theories and case studies (Colby & Sullivan, 2008; Harris et al., 1996; Herkert, 2000; Hess & Fore, 2017). Other methods to teach ESI are community-based learning/community engagement, ethical heuristics, and discussion (Colby & Sullivan, 2008; Haws et al., 2001; Hess & Fore, 2017). Most of the content focuses on individual responsibilities and decisions, as encapsulated in codes of ethics, as opposed to the broader responsibilities of the profession to society and the socio-environmental impacts of technology (Herkert, 2000).

In their multi-case study exploration of engineering programs at seven US institutions, Colby and Sullivan (2008) concluded,

> few of the departments we visited seemed to establish explicit goals in this area or monitor and coordinate coverage. It was commonplace in our site visits for faculty, even department chairs, to be unaware of whether or how their program supports its students' development of professional responsibility or ethics (p. 332).

To improve instructional efficacy and students' professional preparation, it is important to broaden the definition of ethics; include ESI with other learning goals; and increase the intentional integration of ESI in engineering. To achieve these aims, faculty engagement is essential; however, "many faculty members, especially those who are not practicing engineers, are skeptical of the feasibility and legitimacy of this undertaking" (p. 336). The literature thus suggests the need to further explore the role of faculty and their environment in ESI education.

ESI Education by Engineering Discipline

Despite the purported culture of disengagement across engineering, engineering is not a monolith and discipline serves as an environmental influence. Discipline can shape curriculum through the broader role of professional societies, codes of ethics, and bodies of knowledge. For example, the code of ethics for chemical engineering (American Institute of Chemical Engineers [AIChE], 2015a) and electrical engineering (Institute of Electrical and Electronics Engineers [IEEE], n.d.) first include that members must "hold paramount the safety, health, and welfare of the public" and protect the environment. The IEEE code also mentions, "ethical design and sustainable development practices" in the first canon and "societal implications of conventional and emerging technologies, including intelligent systems" in the fifth. The sixth canon in the chemical engineering code includes an "environment of equity, diversity and inclusion", similar to the eighth in the electrical engineering code. The Body of Knowledge for Chemical Engineers (AIChE, 2015b) includes concern for public welfare, ethics, and respect for others in the affective domain and environmental assessment, safety, and sustainability in the cross function domain knowledge and skills. IEEE does not provide a Body of Knowledge for electrical engineering (but does for software engineering, enterprise information technology, and systems engineering). IEEE formed an Ad Hoc Committee on Ethics Education (IEEE, 2018) and The IEEE Global Initiative on Ethics of Autonomous and Intelligent Systems, which developed the report "Ethically Aligned Design" (IEEE, 2018), indicating a commitment to ethics in education and practice. These broader disciplinary forces can directly influence ESI education and percolate implicitly into the local culture of an engineering department.

Given the autonomy of individual program to design curriculum and meet accreditation criteria, the extent to which engineering faculty engage in ESI education varies. A survey of over 600 academics in electrical and computer engineering revealed that 36% of the respondents do not teach moral/ethical reasoning and 48% do not assess it (Lord et al., 2015).

Contribution to the Literature

The literature provides an aggregated examination of the environmental influences on course planning in higher education (Lattuca & Stark, 2009), engineering in Australia (Knight et al., 2016), and ethics in engineering (Katz & Knight, 2017). The present study contributes with an in-depth examination that triangulated multiple perspectives and methods to explore the effect of environment in two engineering departments. This work also focuses on ESI education in engineering, part of curricula that is growing in attention and importance.

Research Questions

How do the academic environment and culture impact ESI education outcomes?

1) What are engineering faculty members' perceptions of the importance of teaching ESI in the two departments?
2) What are the institution, college, and department cultures experienced by engineering faculty in the two departments related to ESI education?
3) What are the personal instructional practices and perspectives related to ESI education of faculty in the two departments?

Methodology

This research employed a case study methodology to examine the effect of academic environment on the ESI instructional practices and perspectives of engineering faculty. This methodology involves the in-depth exploration of distinct instances (Case & Light, 2011; Flyvberg, 2006; Given, 2008; Yin, 2003) and tests existing theory (Matusovich, Streveler, & Miller, 2010). Case study was appropriate for this research because it applied and tested the Academic Plan in the context of ESI education in engineering. Case study is also used because it takes into "consideration the particular idiosyncrasies of the institution… its overall culture" (Case & Light, 2011), which is fitting for the exploration of academic environment. This study uses a multi-case approach (Matusovich, Streveler, & Miller, 2010) with each case defined as a unique department. The two cases were selected to represent variation in the ESI culture to explore a range of settings and influences. The logic of the multiple-case study design is theoretical replication, which "predicts contrasting results but for predictable reasons" (Yin, 2003, p. 47).

Cases

This research is situated in a broader study on ESI education that included an online survey of faculty and staff that collected 1448 responses from over 418 institutions in spring 2016. On the survey, 230 respondents expressed willingness to participate in a follow-up interview. From this group, 37 educators across 35 institutions were interviewed between September 2016 and April 2017 to explore the setting in which they teach ESI and their perspectives on ESI education. Educators in the United States (n=35) who participated in an interview were offered a $50 Amazon gift certificate. Near the end of the interview, participants were asked to describe the culture at their institution related to the ESI education of engineering and computing students. Differences in perceptions of culture were noted based on the institution mission and department size (Polmear et al., 2018). Based on these findings, two departments were chosen for this case study research. The two cases were selected because they appeared to represent divergent cultures despite having similar institutional characteristics since they are both embedded in public, research-intensive universities. The chemical and biological engineering department serving as Case A was described as supportive and the electrical and computing engineering department serving as Case B was described as resistant to ESI education. During a site visit to Case A as part of the broader study, two additional interviews were conducted with faculty members in the chemical and biological engineering department. These interviews corroborated the initial description of a culture that encouraged and supported ESI instruction. A second interviewee from the Institution B but rostered in a different department, expressed a similar perception of culture as the first interviewee in that the college administration and institutional environment encouraged ESI education but department faculty perceived it as outside the realm of technical engineering that should be taught. For the survey that was the foundation of the broader study, 26 educators at Institution A and 41 at Institution B were invited to participate and response rates were similar at 27% and 29%, respectively. The institutional characteristics (Carnegie, n.d.) and departmental level attributes for each case are summarized in Table 10.

Table 10: Case characteristics

Characteristic	Case A	Case B
Institution Control	Public	Public
Institution Basic Type	Doctoral, higher research	Doctoral, highest research
Institution Undergrad Program	Balanced arts & sci/professions, high grad coexistence	Balanced arts & sci/professions, high grad coexistence
Enrollment Profile	Very high undergrad	High undergrad
Undergrad Profile	4-year, full-time, more selective, higher transfer-in	4-year, full-time, more selective, lower transfer-in
Size and Setting	4-year, large, primarily residential	4-year, large, primarily residential
Student Population^	Large	Huge
Dept. faculty (tenured/tenure track, research, instructor, emeritus), n	>20	>100
Dept. undergrad enrollment, n	>500	>2000

^College Data, n.d.

Data Collection

All of the methods were included in a protocol approved by the Institutional Review Board for Human Subjects Research. The case study methodology involved a mixed-methods design and embedded analysis (Yin, 2003).

Interview: The first phase was qualitative with data derived from faculty interviews. After the initial interviews and the selection of the cases, there was interest in gathering more perspectives on culture and environment from other faculty in the two departments since the preliminary interviews included few participants whose opinions could be biased. A snowball sampling strategy was used to expand the number of participants (Noy, 2008). The initial faculty participant from each department was emailed and asked for the names and email addresses of colleagues in their department who are not actively involved in ESI education. The faculty member at Case A sent three recommendations and the faculty member at Case B recommended seven colleagues (including one "ally" in ESI instruction in the department). All of the suggested colleagues were emailed and invited to participate in an interview on ESI education in engineering, whether or not they personally engage in it. The prospective participants were offered a $50 Amazon gift certificate for completing the interview. The faculty member at Case A consented to his name being used in the solicitation email to interview his colleagues and the faculty member at Case B preferred to remain anonymous. Two of the three educators at Case A responded to the invitation and completed an interview. The seven educators at Case B were sent an initial and follow-up invitation but only one (the “ally”) responded and completed an interview. The in-depth (Creswell, 2007), semi-structured (Petty et al., 2012) interviews were conducted by the first author in November to December 2018. Demographic information on the participants is displayed in Table 11.

Table 11: Interview participants

Characteristics	Case A	Case B
Total, n	5	2
Female	2	1
Professor	1	0
Associate professor	2	0
Assistant professor	2	0
Emeritus	0	2

Survey: Due to the low representation and “atypical” characteristics of faculty interviewed for Case B (two emeritus among over 120 total faculty; versus ~20% of Case A faculty), a quantitative method was employed as the next phase of the case study data collection. An online survey was developed in Qualtrics and sent to all of the faculty members in the two departments (tenured and tenure track (T/TT), instructors, research faulty, and emeritus). The respondents were invited to take the survey on February 6, 2019 (wave 1) with reminders sent to unfinished respondents on February 14 (wave 2) and February 25 (wave 3). The survey closed on March 2, 2019. The survey included questions modified from instruments that investigated faculty perspectives on ESI (Bielefeldt et al., 2016), Science, Technology, Society, and Environment (Romkey, 2015), ethical beliefs (Katz & Knight, 2017), and service learning

(Pierrakos et al., 2012). The questions were primarily Likert-type and related to perceptions of the importance of teaching ethics and societal impacts in engineering and the culture experienced by faculty teaching ESI. Respondents were also asked whose responsibility it is to teach ESI and to rank their agreement with a number of statements. The survey then asked questions specific to the respondents' individual instruction including whether they teach ESI and how much they emphasize the importance of ESI in the course they teach most frequently. The survey concluded with questions on the sufficiency of ESI exposure for undergraduate and graduate students in their program and finally, an open-response on their thoughts on the education of engineering and computing students regarding ESI. A copy of the survey is provided in Appendix G.

The name, rank, gender, email address, and year and country of Bachelor's degree for each faculty member were compiled by the first author from the respective department websites. The online survey invitation was emailed to all faculty within the departments. Participants could enter their email address if they wanted to be entered into a lottery for a $100 Amazon gift certificate; one certificate was available for each department. Characteristics of the survey respondents are presented in Table 12. For the demographics shown in Table 12, there were no statistically significant differences between the respondents and overall department faculty for either case.

Table 12: Survey respondents

	Case A	Case B
Active nonrespondent*, n	0	7
At least partial respondent, n	15	24
Response rate, %	68	15
Female, %	40	21
Rank, %		
Professor	33	50
Associate professor	27	0
Assistant professor	27	25
Teaching faculty	13	4
Instructor/lecturer	0	8

	Case A	Case B
Research faculty	0	0
Emeritus	0	13
Bachelor's awarded outside of U.S., %	0	33

*Did not consent, opened the survey but did not answer any questions, opted out of the survey (Halbesleben & Whitman, 2013)

The response rate, the percentage of individuals who completed the survey after being invited, from Case A (68%) was much higher than Case B (15%) (Fisher's exact test, two-tailed $p < 0.0001$). Although response rates are often included as a measure of external validity, "it is a flawed indicator of data quality" (Halbesleben & Whitman, 2013, p. 913). Response rates are problematic because they do not equate to generalizability. However, low response rates still raise questions regarding nonresponse bias (Groves, Presser, & Dipko, 2004), which is the "systematic difference between those who respond and those who do not respond on a substantive construct measured by a survey" (Halbesleben & Whitman, 2013, p. 915). Nonresponse bias impacts the mean values of respondents versus nonrespondents and leads to altered inferences about the relationships between variables (Halbesleben & Whitman, 2013). To mitigate the effect of nonresponse bias, steps in the framework developed by Halbesleben and Whitman (2013) were implemented, displayed in Table 13 and described in more detail below.

Table 13: Nonresponse bias mitigation

Technique	Description	Our approach
1. Compare characteristics of sample to population	Most common approach for assessing nonresponse bias	Compared the rank, gender, decade in which Bachelor's awarded, and country in which Bachelor's was awarded (inside or outside U.S.) for those who were invited (population) and responded (sample)
2. Wave analysis	Compare respondents from each wave	Used initial invitation and two reminders, compared survey responses from individuals in the three waves for each department
3.Benchmarking	Compare against other published data	Compared sufficiency responses for department to their discipline based on data collected in broader study

The rank, gender, and US or international status of Bachelor's degree were compared for respondents and nonrespondents because these characteristics have been associated with differential practices and perspectives related to ESI education (Bielefeldt et al., 2018). The year in which the educators received their Bachelor's degree (grouped by decade) was also compared since the accreditation standards under which they were educated could be impactful, e.g., inclusion of ethical and professional responsibility under ABET EC2000 (Lattuca, Terenzini, & Volkwein, 2006). The characteristics comparison for Case A indicated that the survey respondents (sample) and overall department faculty (population) were well matched in terms of rank, gender, and year and location of Bachelor's degree; this conclusion was based on Fisher's exact tests that yielded all p values >0.1. Comparison of the demographic characteristics of respondents versus overall departmental faculty for Case B also indicated there were not statistically significant differences between the sample and population (all p values> 0.1). This analysis suggests that the survey was not susceptible to nonresponse bias based on rank, gender, and year and location of Bachelor's degree of those who participated compared to those who were invited.

Comparing the timing of individuals who responded to the survey, there were not statistically significant differences (p<0.1) in the survey responses between those in waves one, two, and three for Case B using the Kruskal Wallis test, a nonparametric test for more than two samples (Gao, 2010). For Case A, there were statistically significant differences between respondents in the three waves for six of the 27 survey items. Additional information on the characteristic comparison, wave analysis, and benchmarking are included in Appendix H.

Low interest in a survey topic has been associated with low response rates (Lippman et al., 2012). This relationship can be explained by the leverage-salience theory, which postulates that different parts of a survey such as the topic, sender, and incentive have varying weights in determining if an invitee will take the survey (Groves, Presser, & Dipko, 2004). The impact of each part will depend of leverage (importance assigned by the individual) and salience (emphasis in the survey request). In considering the various aspects of a survey, "topic is particularly likely to lead to 'nonignorable' nonresponse, that which produces nonresponse error" (Groves, Presser, & Dipko, 2004, p. 3). This potential bias should be accounted for in generalizing the survey responses to the department since those who do not teach ESI or support ESI education may not have responded to the survey. The difference between the response rate for Case A and B (68% and 15%, respectively) might then suggest lower interest in the survey topic within the department faculty at Case B. There are not expected to be differences in salience based on sender (the second author emailed out the survey invitation and is not from the institution nor discipline of either case) or incentive (same $100 incentive to be awarded randomly to one individual per case).

Document analysis: The third method embedded in the case study methodology was document analysis. Data were collected from institution, college, and department documents that were publicly available online. Document analysis describes the "systematic procedure for reviewing or evaluating documents" (Bowen, 2009, p. 27). This approach "is particularly applicable to qualitative case studies" (p. 29) because "documents can provide data on the context within which research participants operate" (p. 30). In addition to providing data that can complement interview findings, document analysis is also valuable for triangulation, the "use of different data sources and methods" to "seek convergence and corroboration" (Bowen, 2009, p. 28). Table 14 provides a summary of the documents that were collected at the institution, college, and department levels.

Table 14: Documents collected at each level of the environment

Document	Department	College	Institution
Mission	x	x	x
Vision		x	x
Educational objectives	x		
General education/core requirement			x
Outcomes	x		
B.S. Curriculum	x		
Course descriptions	x		
Faculty directory (including linked CVs and websites)	x		

Data Analysis

Interview: All of the faculty interviews were audio recorded and transcribed using Trint software. Denaturalized transcription was employed in which stutters and nonverbals were removed. This approach is common when the focus is informational content as opposed to conversation analysis research for which naturalized transcription includes all verbal and nonverbal details (Oliver, Serovich, & Mason, 2005). As a result, the interview quotes presented in this paper are included to accurately reflect the substance of the discussion while omitting pauses and stutters for clarity. The transcripts were imported into Dedoose for qualitative analysis by the first author using the constant comparative method (Glaser, 1965). The first step in this method was reading through the entire data set, the seven transcripts. The data were then broken into smaller units of analysis (segments) and labeled with a thematic code. Some codes were developed *a priori* based on the research questions (including perceptions of the importance of ESI and culture experienced by faculty) while others emerged in the data, reflecting deductive and inductive coding, respectively. Throughout the analysis, comparisons were made between and within the transcripts so that the codes were appropriately developed and consistently applied. A preliminary codebook was created after the first iteration, which was used to revisit all of the transcripts to develop a final codebook. Multiple coding, a process to check codes and interpretations across multiple researchers (Barbour, 2011), was used for reliability. For this process, the codes and a sub-set of segments (25 of 150) were shared with the second and third authors. The three authors met in-person to read each segment and discuss its thematic codes until convergence was reached.

Survey: The survey data were analyzed with descriptive statistics. Nonparametric statistics, medians and mean ranks, were used since the data did not meet the assumptions of a normal distribution (Gao, 2010). The Mann-Whitney U Test was used to compare the two independent samples (respondents from each department) and test for statistical difference. This test is viewed as the nonparametric alternative to the t-test and uses the rank-order of the two samples so that if the null hypothesis is correct, the two samples have a similar mean rank when the data is pooled (Rorden, Bonilha, & Nicholas, 2007). Since the test is calculated on rank, the mean rank is reported as the output with the higher mean rank having the greater number of high scores. The Mann-Whitney test is appropriate for unequal and small samples (Hinton, 2012). Responses to the open-ended question at the end of the survey were analyzed using emergent, thematic coding (Creswell, 2007).

Document analysis: The documents were analyzed using a combination of content and thematic analysis, as described by Bowen (2009). The content analysis involved a first-pass review and superficial examination (skimming). This process identified relevant portions of the documents and categories related to the research questions such as institutional emphasis on, and curricular inclusion of, ESI (e.g., ethics, societal impact, sustainability, environment) into which the information was organized. Thematic analysis was conducted to recognize patterns in the data and emergent themes. Some themes were developed *a priori* based on the research questions (e.g., culture at the department, college, and institution levels and importance) since “predefined codes may be used, especially if the documents analysis is supplementary to other research methods” (p. 32). The purpose and audience of the documents were also considered.

Limitations

A number of measures were taken to mitigate limitations associated with the case study methodology and establish validity and reliability. Yin (2003) outlined four conditions for design quality of case studies: construct validity, internal validity, external validity, and reliability (p. 34). These conditions and our approaches to fulfill them are summarized in Table 15.

Table 15: Case study design

Test	Tactic	Our approach
Construct validity: “establishing correct operational measures”	Use multiple sources of evidence	Interviews, surveys, documents
	Establish chain of evidence	Documented procedures from development of research questions, derivation of data, analysis of data, and formation of findings
	Have key informants review draft of case study report	Member checks for initial interviewees on their perception of culture and environment
Internal validity: establishing a causal relationship	Do pattern-matching	Data was mapped to the theoretical framework to explore patterns and check for alignment between empirical and predicted pattern
	Do explanation-building	Connected data to theoretical proposition (Academic Plan) to explore causal links between internal influences and educational outcomes
	Address rival explanation	Considered influence of discipline
External validity: establishing the domain to which a study’s findings can be generalized	Use replication logic in multiple-case studies	Examined nonresponse bias to ascertain generalizability to whole department
Reliability: demonstrating that the operations of a study… can be repeated with the same results”	Use case study protocol	Operationalized procedures in IRB-approved protocol and applied consistently to all case studies
	Develop case study database	Archived interview transcripts, survey responses, and documents

One important caveat in this analysis is the influence of discipline. Since the cases represent two different disciplines, differences could be attributed to the disciplinary culture as well as the local department culture. Disparate cultures have been acknowledged within engineering disciplines (Godfrey, 2014). These variations, as embodied in disciplinary codes of ethics and bodies of knowledge, can influence ESI education. Previous research has explored variations in ESI-related topics taught by engineering faculty in 13 disciplines while controlling for individual and institutional confounding variables. Results indicated statistically significant differences for the extent that faculty taught the ESI topics of safety, environmental protection issues, decisions under uncertainty, and sustainability in their courses (Bielefeldt et al., 2019). For example, the study found that 60% of chemical engineering respondents taught environmental protection compared to 17% in electrical engineering. Katz and Knight (2017) found that electrical engineering faculty emphasized the importance of ethical issues in their courses less than faculty in other disciplines but beliefs that ethical issues should be included in multiple courses were not statistically different between electrical and chemical engineering faculty. Considering this rival explanation is part of establishing internal validity but broadly comparing the practices and perspectives across disciplines is beyond the scope of this paper.

Results and Discussion

The results are presented by research question in three sections: perceptions of the importance of teaching ESI, culture experienced by engineering faculty related to ESI education, and personal practices and perspectives related to ESI instruction. The quantitative and qualitative results are presented together in each section.

Research Question 1: Importance

The survey started with 9-point Likert-type questions on the importance of teaching ethics and societal impacts of engineering and technology in engineering education. For the first two items the scale was anchored at 1 very unimportant, 5 neither important nor unimportant, and 9 very important. For the third and fourth items comparing ESI importance to math, science, and engineering, the scale was anchored at 1 significantly less important, 5 equally important, and 9 significantly more important. The results are summarized in Table 16, with the median based on a scale of 1 to 9 and the mean rank within the pooled 39 responses.

Table 16: Ratings of ESI education importance

Rate the importance of:	Case A		Case B		Mann Whitney p value
	Median	Mean rank	Median	Mean rank	
1. Teaching ethics in engineering education	8	18.9	9	20.7	.638
2. Teaching the societal impacts of engineering and technology in engineering education	8	18.5	9	20.1	.687
3. Ethics in engineering education relative to math, science, and engineering science content	5	20.8	5	19.5	.743
4. Teaching students about the societal impacts of technology relative to math, science, and engineering science content in engineering education	5	20.8	5	19.5	.743

Faculty from the two departments indicated that both ethics and the social impacts of engineering and technology are very important in engineering education. There was one low outlier (rating of 1 or 2) for each case related to the importance of teaching ethics and those two individuals gave the importance of teaching societal impacts a rating of 3. Perceptions of importance were slightly higher for Case B but the difference was not statistically significant. When asked about the importance of these topics relative to math, science, and engineering content, respondents in both departments indicated that ESI is equally important (5 on the Likert scale). The results are encouraging in terms of the value that engineering faculty place on ESI in engineering education. There were eight total responses to the open-ended prompt, "please share your thoughts about the education of engineering/computing students regarding ethical issues and societal impacts" and six (three from Case A and three from Case B) mentioned the importance of ESI. An educator at Case A noted, "Fundamentally, an engineer must take into consideration both ethical issues and societal impacts to be a valuable member of society." An educator at Case B also emphasizes this responsibility since "issue[s] such as climate change are very important for the future of humanity. All students need to become very sensitive to these issues." These comments allude to the macroethical responsibility of engineers to society and the importance of fostering that sense of responsibility in engineering curricula.

One potential threat to validity to note in the survey analysis is social desirability bias (SDB), "the pervasive tendency of individuals to present themselves in the most favorable manner" (King & Bruner, 2000, p. 80). SDB is a viable consideration in this survey because "due to the sensitive nature of ethics research, the presence of a social desirability bias may pose an even greater threat to the validity of findings" (Randall & Fernandes, 1991, p. 805). In addition, if leverage-salience of the topic impacted the low response rate from Case B, the respondents may not be broadly representative of the opinions of all faculty in the department. The number of 'active nonrespondents' for Case B somewhat seems to support this concern.

The interviews provided more detailed insight into educators' perspectives on the importance of ESI. Interview segments related to importance were coded into four categories, as shown in Table 17. The theme "importance" was developed *a priori* and the four sub-codes were emergent.

Table 17: Importance sub-codes

Sub-code	Definition
Necessary skills for engineers	Ethical awareness, ethical reasoning, understanding of societal impacts are essential skills for engineers
Integration of ESI and technical content	ESI should be taught in engineering courses and with technical content
Societal responsibility	Engineers have a unique responsibility to society that necessitates eth
Accreditation	ESI is important in engineering education to fulfill accreditation criteria

ESI broadly captures a range of topics related to microethics and macroethics. Some of the interviewees appeared to frame ESI in terms of microethics by discussing the importance of worker safety and academic integrity. Other interviewees conveyed the value of macroethics by explaining the importance of teaching social justice and environmental protection. One interviewee explained that if engineering ethics is a valued skill, it needs to be treated the same as other engineering skills in the curriculum.

> I think like any skill if we think it's important it needs to be developed with repeated practice with feedback… Otherwise we're just talking hot air and the students aren't going to leave with anything, any lasting effect. [Case B]

However, the interviewee explained that this personal perspective on the importance of ESI was not mirrored amongst colleagues in the department.

> There is this feeling that if it's not technical then it's not something we want to be teaching in the department. So I have other sort of non-technical engineering courses that I proposed such as this technology society course have been turned down because they say well, it's not their understanding of what engineering is. [Case B]

Another interviewee explained that teaching ESI in the context of technical courses is an effective approach for increasing students' exposure while working within the constraints of the curriculum.

> Curricula are very jam packed with technical content… I think there's a sentiment that integrating sustainability or ethics comes at the end at the expense of technical content. It's my view or hope that we can, so to speak, kill two birds with one stone; teaching the technical content and the implications of that technical content visa vie sustainability or ethics. [Case A]

There are multiple implications for importance couched in this statement. The interviewee suggested that other engineering educators may perceive sustainability or ethics and technical content as mutually exclusive and favor emphasis on the latter. This finding aligns with the social/technical dualism cited as one of the pillars of the culture of disengagement in engineering (Cech, 2014). To circumvent this challenge, the interviewee taught the technical content and ESI in tandem since both are important and complimentary.

Document analysis was employed to explore if faculty members' perceptions of importance were reflected formally by the department. Case A has six educational objectives including students being "highly ethical" and embracing safety as two stand-alone objectives. Case B has five objectives, including high ethical standards but this objective is coupled with communication.

The undergraduate curriculum and course descriptions for each department based on the catalog were also analyzed. At Case A, ESI is mentioned in the description of a required sophomore-level course that covers contemporary issues and societal context. Although interviews with multiple faculty at Case A discussed the coverage of ESI in capstone design, ESI was not explicitly included in its course description. At the college level, capstone design across all engineering programs is described to include economic, societal, and global context, which alludes to macroethical integration into projects. At Case B, ethics and professional responsibility are included in the course description for an introductory course. The course website for senior design at Case B notes the expectation that projects are ethical and safe. The senior design course site also has a section dedicated to ethical guidelines, which emphasizes students' familiarity with the code of ethics and considerations of its relevance to their projects. Both programs require 128 credits for graduation but only appear to explicitly cover ESI in one required three-credit course. However, the descriptions in the catalogs were very short, an average of 22 and 45 words for each course at Case A and Case B, respectively. Future work could include course syllabi and ABET self-study reports to glean a more complete understanding of course content.

Research Question 2: Culture

The survey and interview protocol included questions on institution, college, and department culture to understand if these environmental factors were influential in faculty's course planning. The ratings from the survey are shown in Table 18, based on a 1 to 5 scale. The scale for the first item was anchored at 1 (very unsupportive), 3 (neutral), and 5 (very supportive). The scale for the other items was anchored at 1 (strongly disagree), 3 (neutral), and 5 (strongly agree).

Table 18: Ratings of culture

Survey Item	Case A		Case B		Mann Whitney p
	Median	Mean rank	Median	Mean rank	
Describe the culture experienced by faculty teaching ethics and societal impacts to engineering and computing students:					
At your institution	4	19.5	4	18.6	0.819
In your college	4	21.7	4	18.1	0.344
In your department	5	23.7	4	16.7	0.059*
The college dean is supportive of teaching ethics and societal impact topics.	5	21.3	4	17.4	0.290
The department head/chair is supportive of teaching ethics and societal impact topics.	5	23.8	4	16.9	0.078*

	Case A		Case B		Mann Whitney p
	Median	Mean Rank	Median	Mean Rank	
Other faculty in the department/program are supportive of teaching ethics and societal impact topics.	4	22.6	4	17.5	0.172
*p<0.1					

For Case A, perceptions of support increase from institution to college to department. The opposite trend is apparent for Case B with the highest mean rank for institution and lowest for department. The faculty perceptions of department level support for ESI teaching is different between the two cases, with a 90% confidence level ($p<0.1$). This significance level to infer difference is not atypical for analysis of small datasets (Dodge, 2008). College and institutional support for ESI teaching are not perceived to be different between the two cases.

<u>Institution:</u> At the institutional level, document analysis supported the similarity in culture reflected in the survey responses. Both have land grant missions that espouse commitment to engagement, learning, and discovery and serving their community and enhancing the lives of others. Both institutions have visions that relate local to global impact and include engagement, education, and research. This result is unsurprising as there is little diversity in mission and vision statements and most institutions follow a certain typology with similar values (Morphew & Hartley, 2006). Both institutions have a general education/core requirement for all students of 18 credits in social science, humanities, and arts (27 at Case A but the difference is met by required courses in the program). From the extensive catalog of courses that fulfill these requirements, there are a number at both institutions that relate to ESI.

Interviews with respondents in both cases suggested a strongly supportive institution-level culture related to ESI education. Two interviewees at Case A described that university leaders helped create an institutional support for ESI education. One interviewee explained, “I do believe our values trickle down from the top” and cited university policies on academic misconduct and practices related to local sourcing and ethical farming for food on campus as examples. Another interviewee from Case A noted the support of university administration and its positive effect on his teaching, “the messaging that they're getting across is that this is very important and they're very encouraging of faculty like myself. So there's a, I think, administratively or top down push to try to do more of it.”

An educator at Case B described how the campus-wide emphasis on professional responsibility supported ESI education and facilitated collaboration across departments.

> So ethics education at [Institution B] is actually, it's pretty positive… It's actually been nice that I've been able to talk to people in many departments, [Institution B] has very strong pre-professional ethos. So besides engineering… there are also pre-professional programs in social work, library science, [and] law… So the idea is of professional ethics is absolutely ingrained across the campus. [Case B]

In these two cases, the institution-level ESI culture and support seemed very similar. This contrasts with results of other studies. For example Bielefeldt et al. (2019) compared 22 institutions and found differences among educators of engineering and computing students in the extent that five ESI topics were taught (social justice, engineering and poverty, societal impacts of engineering/technology, ethical theories, and codes of ethics). There were also differences in the extent to which faculty at different institutions believed students in their programs learned about ESI in three courses: first-year design, professional issues, and a full course on ethics. Institutional differences have also been reported between religious and secular institutions with faculty at religiously-affiliated institutions teaching risk and liability, engineering and poverty, social justice, ethical failures, safety, and societal impacts more frequently (Bielefeldt et al., 2016c).

College: Both cases had a median of 4 for college culture; although the mean rank for Case A was higher, it was not statistically different. These results were supplemented with interview and document analysis. All five interviewees from Case A mentioned the dean when asked about the college of engineering culture. One interviewee, the department head, noted that the department was motivated to include ESI beyond minimal compliance required for ABET, which stemmed from the dean and noted, “the push that I feel to make sure that we teach ethics robustly… come from the College of Engineering Dean.” Another interviewee who teaches ESI in the context of sustainability, noted,

> I feel a large amount of encouragement from certainly the department head and dean in integrating ethics issues into engineering coursework. Based on getting feedback that I receive both formally and informally, they're very receptive of this, appreciative in fact. [Case A]

Two of the interviewees cited the dean’s support for women and creation of a culture that fosters diversity and inclusion. These are tenets of ESI as indicated by the inclusion of “fostering an environment of equity, diversity, and inclusion” in the chemical engineering codes of ethics (AIChE, 2015). Inclusiveness is included as one of the college of engineering’s core values. A male interviewee noted that the dean “really openly pushes women’s involvement in engineering” and a female interviewee explained that the tone set by the dean created a “college culture [which] is fabulous in terms of supporting women and helping… males realize the value of diverse groups of people.” One interviewee noted that the creation of this culture was facilitated by a personal change for the dean. The interviewee described a conversation he had with the dean in which the dean noted that his perspective on ESI had evolved.

He said basically that he always thought there was someone else's job to handle ethics and broader societal impacts. But now he's starting to see it as an obligation that we have as engineers and I thought that was really a cool thing to hear. [Case A]

With a leadership role and ability to set the tone for the college, the dean was instrumental in creating a culture that supports ESI instruction.

Two educators at Case A also mentioned a multidisciplinary design course as evidence of college-wide support for ESI instruction. This course facilitates teamwork across disciplines and introduces students to ethics during their junior year in the context of a design project. ESI is not mentioned in the catalog description of that course but it includes design, teamwork, and leadership. When asked about the college culture, an interviewee explained,

The only thing I can think of on the college level that points to that is that the college has a junior design course that is multidisciplinary where students across different engineering disciplines work together…And that was adopted college wide and supported college wide and by the dean. So that's one little piece of evidence that there is a culture college wide. [Case A]

When the interviewees at Case B were asked about environmental culture, they focused on departmental and institutional level and thus with only two interviews, no conclusions could be drawn. The College B mission statement mentions serving the state and nation and benefiting society and the vision statement includes ethical values, suggesting macroethical commitments. The college website touts research expenditures and rankings, conveying an outward facing emphasis on these outcomes as well.

Department: As noted above, the survey results revealed a difference in the perception of support at the department level. Survey respondents indicated their level of agreement that “the department head/chair is supportive of teaching ethics and societal impact topics." There was a statistically significant difference between the two cases; the mean rank for Case A was 23.47 and 16.91 for Case B (p=0.078). This finding is corroborated by the results from the survey question that asked the percentage of faculty in the department who teach ESI (Table 19). At Case A, the median response was that over half of the faculty teach ESI, compared to a median of 10-25% at Case B. The results somewhat align with number of respondents from each institution; 13 respondents from A teaching ESI (59% of faculty in department) vs. 16 respondents from B teaching ESI (10%).

Table 19: Survey responses: percentage of faculty in department believed to teach ESI in one or more courses

Percentage Range	Case A (n=12), %	Case B (n=20), %
0-10%	0	30
10-25%	8	25
25-50%	33	35
>50%	58	10
(unsure, n, not included in % calculations)	*(3)*	*(2)*
Weighted 'average' (middle of each category and 50% for highest)	*43%*	*24%*

The interviews shed light on the divergent perceptions of department culture for the two cases. All five of the interviewees from Case A expressed that the positive department culture in regards to ESI education stemmed from the nature of the faculty within it. The faculty value ESI instruction and share a commitment to it in their courses. One interviewee expressed, "I do feel like we've established a faculty that all individually perceive it as our obligation to integrate ethics into our courses to the extent that we can." Another interviewee echoed, "I think every faculty tries to incorporate it somewhat into their class." As a result, the integration of ESI into the engineering curriculum has emerged bottom-up. A third interviewee explained the development of this culture.

> It's not necessarily top down, it's more like as a faculty we've had a discussion and people kind of agree that it's important and some of that discussion has been initiated by the design instructors saying ‘this is what we do in design but we don't want it to be the first time that the students hear about safety and ethics so how can we incorporate it in the class?’ [Case A]

A fourth interviewee cited the recent hiring of a non-tenure track faculty member with 40 years of industry experience who “can put in more of that ethics and real world to teaching” as an indicator of how ESI instruction is valued by the department. The department head mentioned during the interview that the department chose not to offer or require an ESI-specific course and instead cover the topics across the curriculum.

> We've found that the best, most effective way for us to do ethics is not a single class or a single part of a single class but multiple, multiple times… It's my job and it's our job as a faculty to make sure that ethics is comprehensively covered and the way that we achieve that is … content in multiple classes. So we have a few classes like the design class where it's pretty heavily emphasized and that's where we want to assess it and make absolutely sure our students before they graduate have a good understanding of ethics. However we don't want to limit ourselves to just that one class and so we have ethics content in other classes throughout the curriculum. [Case A]

A bottom-up approach, based on the motivation and initiative of individual educators, can be an effective way to leverage the interests of faculty (Knight et al., 2016) and support the broader integration of ethical and societal considerations. However, this approach can lead to somewhat haphazard exposure and is contingent on the effort of individuals.

The department at Case B was described as not supportive in the initial interview that was used to select the cases for further exploration. When asked about challenges in developing and teaching courses related to ESI, the interviewee shared obstacles in the department.

> There's fierce resistance from the rest of the Department of Electrical and Computer Engineering… The faculty generally believe that engineering knowledge, all engineer knowledge, is technical. They seem not to understand that engineering ethics is part of the non-technical knowledge that engineers need to have, just as say project management is an example of non-technical knowledge that engineers need to have. [Case B]

The other interviewee, who served on the curriculum committee when ABET EC2000 was introduced, described similar resistance from colleagues. The interviewee explained that the inclusion of ethical responsibility in program criteria generated extensive discussion and revealed the department's value on this outcome.

> It was a very interesting discussion … the typical kind of statement is, 'I show ethics by my wonderful teaching example' and 'oh of course I bring it in, I do this or that,' All of which was pretty meager, grasping at straws really without putting any ethics in there…But there really was a very strong sense that trying to teach ethics was not worthwhile because it's not technical and we don't have technical materials in it then … it doesn't have a place… There was definitely a feeling there's not room in our program for it. So basically how can we get past … this ABET requirement and not do anything. [Case B]

The department decided that the accreditation criterion would be fulfilled with one week of ethics instruction in a sophomore-level course that the interviewee taught. Although a second course in the curriculum was designated for ethics, the instructor of that course never came to the planning meetings with the philosophy consultant hired to help with the integration and refused to include the topics in the course. Confronted with the accreditation requirements, "the directive from the department was basically none. It was save our department 'til we get ABET accredited. And so I felt a fairly big responsibility." The department had a culture of minimal compliance that did not support the sole educator who was tasked with teaching ethics. In response to the open-ended prompt on the survey, one educator at Case B noted "only fraction of students takes a course with substantial content on engineering ethics and mainly if the course satisfies a requirement, e.g., for general education or honors program."

It is important to note the temporal limitations of the interview perspectives. Since only two educators at Case B participated in interviews, the analysis is limited to their experiences and perceptions. And since both are faculty emeritus, the findings may not reflect the current state of the department culture. One interviewee alluded to this change and said, "I think the department is becoming stronger." The interviewee went on to explain if the ABET accreditation criteria change had been introduced under the recent department head's leadership, "he would have done a much better job of talking to the faculty and supporting and saying, explaining, why this is a good idea." The current program outcomes suggest an emphasis on these issues. The outcomes were expanded beyond ABET A-K to include ethics and sustainability as design constraints. The archived catalog from 2003, for example, lists the program outcomes as the same as ABET EC2000 and one of the educational outcomes included ethics but has since been modified to highly ethical standards.

Research Question 3: Personal instruction

The interviews and surveys sought feedback on personal practices and perspectives related to ESI to understand how the environment might have shaped them and if there were any differences between educators in the two cases. The survey respondents were asked if they teach ESI to undergraduate or graduate students, the results are presented in Table 20.

Table 20: Personal ESI instruction

Teach engineering and/or computing students about ethics and/or societal impacts:	A, % (n=15)	B, % (n=21)
Yes, in undergraduate courses	87	76
Yes, in graduate courses	20	38
I teach undergraduate courses but they do not integrate ethics or societal impacts	13	29
I teach graduate courses but they do not integrate ethics or societal impacts	7	19
I do not teach courses for engineering or computing students	0	0

The responses indicate that the majority of participants who responded to the survey in both departments teach ESI to undergraduate students. Comparing these data with the estimated percentage of faculty in each department who teach ESI suggests that ESI educators are oversampled in the survey relative to the population. However, the "oversampling" appears much greater for Case B where only 10% of the faculty respondents (n=2) believed >50% of the faculty in their department integrated ESI; 58% of the Case A respondents indicated that >50% of the faculty in their department taught ESI. The results also indicate that only four respondents at Case A are engaged in graduate teaching versus over half of the respondents from Case B. It is worth noting that this question does not capture that quantity or quality of ESI instruction. To get a better understanding of the degree of coverage, respondents were asked how much they emphasize these topics in the course they teach most frequently. The results are presented in Table 21; the scale was 1 (little/no emphasis) to 5 (strong emphasis).

Table 21: Emphasis on ESI in course individual teaches the most frequently

How much do you emphasize:	Case A		Case B		Mann Whitney p
	Median	Mean rank	Median	Mean rank	
the importance of ethical issues in engineering and/or computing	3	21.5	3	18.2	0.375
the importance of societal/environmental impacts	4	23.0	3	17.2	0.121

The data indicate moderate emphasis at Case B and greater importance placed on societal and environmental impacts at Case A. This finding aligns with the disciplinary emphasis on sustainability and environmental protection in chemical engineering (Bielefeldt et al., 2019).

The interviewees were also asked about the courses they teach and if they integrate ESI into these settings. One interviewee at Case A, who was referred by the colleague when asked for recommendations of educators in the department who do not teach ESI, described the inclusion of ESI.

> There are small examples that are woven throughout in terms of safety considerations. Nothing big or nothing that I can point to an outcome like a homework or a project or anything. But I do try to mention things… when we're talking about a design of heat exchangers, I give them the technical stuff but then we also have discussion on what are your design parameters…What are the cost benefits? And safety comes into that and as well as economic costs and other types of things. So I would say that is informally what I do. Ethics, again, I don't think there's anything like formally point to as an outcome but I think it's really important for engineers to have ethics and integrity just because of the nature of what we do. So I try to emphasize that a lot and I try to tell them, "you guys have to have honesty and integrity right now because when you go into the workforce… cutting corners can get people killed." [Case A]

The other interviewee from Case A who was recruited through this process described a similar approach of teaching ESI in foundational engineering courses via brief examples and discussions.

> So for example, in separations I talk about when we're selecting solvents, you've got to consider the toxicity and the harmfulness. We talk about strippers, which remove the

volatile organic compounds from effluent streams from plants, to keep your neighborhood community healthy. [Case A]

Their experiences illuminate the opportunity for micro-insertions of ESI in technical courses (Davis, 2006). This approach introduces ethics to provide context and relevance in engineering courses without forcing out technical material since it is introduced in small units.

The interviewee at Case B who taught the course in which ethics were embedded post-ABET EC2000 covered the topics via lecture, discussion, and homework. Based on experience with training teaching assistants (TAs) to lead discussions in recitation; posing ethical dilemmas on assignments; and asking students to reason through their course of action, the interviewee found that a lecture on ethical mistakes was most effective for engaging students. Real examples that illustrated the consequences of ethical missteps in electrical engineering captured students' attention and provided context on the high stakes of the profession.

The study explored engineering faculty member's perspectives on ESI instruction in additional to their personal practices. The survey respondents were asked whose responsibility it should be to teach ESI; results are displayed in Table 22 with a 1 (strongly disagree) to 5 (strongly agree) scale.

Table 22: Level of agreement on responsibility to teach ESI

ESI teaching should be the responsibility of instructors of courses in:	Case A		Case B		Mann Whitney p
	Median	Mean rank	Median	Median rank	
Humanities/social science	4	23.63	3	16.80	0.064*
Engineering ethics	5	24.40	4	16.30	0.028*
Engineering design	4	21.80	4	18.00	0.314
Math, science, engineering science	4	21.80	4	18.00	0.314
All across undergraduate engineering curriculum	4	20.43	4	18.89	0.680
					*p<0.1

There was a statistically significant difference between the two departments for level of agreement that ESI should be taught by instructors of engineering ethics and humanities/social science courses. This result could indicate that respondents at Case B prefer a more practical approach to ESI instruction than a humanities, social sciences, or ethics specialist may offer.

Conclusions

The scale of development and emergence of new technologies will usher the next generation of engineers into uncharted territory in understanding environmental and social impacts of engineering. As a result, the engineering profession necessitates an understanding of ethical responsibility and societal context to navigate these challenges and "hold paramount the safety, health, and welfare of the public" (NSPE, 2018). Since engineering faculty will play a key role in the integration of ESI in the curriculum, it is important to understand influences on their course planning. This study was grounded in the Academic Plan framework and case study methodology to examine one such influence, academic environment, on faculty members' ESI education outcomes. Data were collected and triangulated from faculty interviews, survey, and document analysis to understand perceptions of ESI importance, culture, and teaching practices.

Survey respondents from the two departments rated the importance of teaching both ethics and the societal impacts of engineering and technology highly. The results indicated that educators considered ESI of equal importance as math, science, and engineering content. However, these findings may not represent the majority of faculty in the department for Case B, given the survey respondents represented only 15% of the faculty in the department (versus 68% for Case A). The interviews illuminated nuances to these perceptions of importance such as the need to develop ethical awareness and reasoning skills, meet accreditation criteria, integrate technical material and its broader impacts, and convey the societal responsibility of the profession. Despite this importance, document analysis of the curriculum and course descriptions from the catalog revealed that ESI was explicitly included in very few required courses in both departments.

This study explored the influence of culture at the level of the department, college, and institution. Survey results indicated similar perceptions of college and institution culture at both cases. This finding was corroborated with interview data and document analysis. The department climate and leadership appeared to have acute effects on faculty members' perceptions of support and suggested the point at which the two cases diverged. A greater portion of faculty at Case A were believed to engage in ESI instruction creating a engaged culture that was bolstered by a supportive department head.

The majority of survey respondents in both departments indicated teaching ESI to undergraduate students with a moderate emphasis on these topics. The interviews offered multiple ways of teaching ESI including micro-insertions in technical courses and using different lenses to view ethics based on the context of the course. These approaches enabled the integration of ESI even if it was not included as an explicit outcome of the course.

Implications and Future Work

This research used a case study approach to knit together multiple pieces of evidence and explore the impact of environment and culture on engineering faculty relative to ESI education. The results illuminated implications for faculty's course planning and opportunities for additional inquiry.

A supportive culture can be balanced from bottom-up and top-down approaches. Establishing a critical mass of faculty who value, and engage in, ESI instruction fosters a climate of support for those educators and broadens students' exposure to these topics across the curriculum. Explicit directives from department leadership can also facilitate this integration especially since effects may be more acute at the department level.

The results also indicated the importance of aligning formal structures and policies with implicit values and assumptions. Survey data showed only moderate agreement that ESI teaching is valued in annual evaluation reviews and promotion and tenure reviews (more detail included in Appendix I). The ways in which the environment conveys the importance of ESI, inward and outward facing, can affect the culture experienced by the faculty. The potential disconnection between the espoused value of ESI and its implicit deprioritization through minimal curricular coverage can also affect students' learning through the hidden curriculum (Hafferty & Gaufberg, 2017; Margolis, 2001).

Academic environment is the result of many factors but is also just one of many influences on course planning. Future research could explore some of the structural and cultural variables such as teaching load, research expectation, and faculty composition, and how they affect faculty members' perception of the environment and their instructional practices within it. Disciplinary effects could also be isolated by using a case study methodology with departments of the same disciplines at different institutions.

With increasing attention paid to the inclusion of ESI and growing responsibility on engineering faculty, it is important to acknowledge the environment in which faculty develop their instructional practices and perspectives. This consideration mirrors the emerging trend of conceptualizing ethics macroethically instead of microethically (Herkert, 2001; Zandvoort et al. 2000). Framing ethics individualistically with an emphasis on the role and autonomy of engineers averts attention from the broader context (Conlon & Zandvoort, 2010). Engineers do not make decisions regarding ethics in a vacuum and nor do engineering educators. An understanding of context and culture and how their influences percolate into the teaching of individual faculty can facilitate reflection on the role of the environment and how it can be shaped to support ESI education and educators.

Chapter VI: Cultural Environment

Analysis of Macroethics Teaching Practices and Perceptions in Engineering: a Cultural Comparison[1]

Abstract

Students must be taught to understand the ethical issues associated with engineering and technology, which includes microethics and macroethics. This research examined the influence of cultural environment by comparing ethics-related education outcomes between educators in (1) the United States, (2) non-US Anglo, and (3) Western European countries who teach engineering students. In an increasingly globalized world where companies and projects draw from talent across countries, it is important to understand how different cultures educate future engineers about their ethical responsibilities. Survey results revealed that a majority of educators in all three groups viewed undergraduate and postgraduate education on ethics as insufficient. A higher percentage of non-US Anglo and Western European educators taught sustainability and environmental issues in their courses compared to US respondents. US educators taught codes of ethics, ethics in design, and safety more than those in Western Europe. Open-ended responses illuminated challenges and opportunities to improve ethics education.

Introduction

Engineers are part of an increasingly mobile workforce and 'will work in other countries or be employed alongside people who have been trained in other countries' (Lucena et al., 2008, p. 433). This necessitates global competency in engineering and an awareness of how different

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[1] Madeline Polmear, Angela R. Bielefeldt, Daniel Knight, Nathan Canney & Christopher Swan (2019): Analysis of macroethics teaching practices and perceptions in engineering: a cultural comparison, European Journal of Engineering Education, DOI: 10.1080/03043797.2019.1593323

cultures educate their students. International efforts to prepare students to work in global environments pertain to both technical problem solving and professional skills (Downey et al., 2006). This paper aims to better understand similarities and differences in ethics education across cultures to support educators in preparing globally competent engineers.

An input-environment-output model (Astin, 1993; Lattuca & Stark, 2009) served as the foundation of the work. This framework posits that environment exerts an influence on educational outputs. This paper asserts and tests the hypothesis that environment, which we conceptualized with the GLOBE cultural clusters (House et al., 2004), affects ethics-related outputs (perceptions of sufficiency, topics, and broad perspectives) when controlling for inputs. The research compared survey respondents teaching at institutions in the United States (US) to non-US Anglo and Western European countries to discern similarities and differences in terms of the sufficiency perspectives and ethics-related topics taught in courses.

Macroethics

Ethical awareness and reasoning are important skills for students entering the workforce and tackling complicated engineering challenges, and should span both microethics and macroethics (Herkert, 2003). Microethics is focused on individual responsibility and day-to-day ethical decisions, such as not accepting bribes and working within your area of competence, while macroethics includes broader ethical considerations of the profession and the societal impacts of engineering, including sustainability and social justice (Herkert, 2001). In engineering education in the US, there is often a lack of awareness of these two domains of ethics, which often leads to the prioritization of microethics and the omission of macroethics (Herkert, 2005). Conlon and Zandvoort (2010) advocated a Science, Technology, and Society (STS) approach in European engineering programs to teach macroethics as opposed to the individualistic approach often taken in engineering ethics. Son (2008) suggested that the macroethical approach could be improved and complemented with lessons from the philosophy of technology. Educators in Canada (Hudspith, 1991) and Ireland (Byrne, 2012) have similarly promoted macroethics to broaden and contextualize engineering ethics instruction. Despite the global importance of macroethics education, there are a number of barriers to its inclusion such as a narrow technical focus in engineering education and lack of faculty expertise (Haws, 2001).

Theoretical Framework

An inputs-environments-outputs (IEO) model was used to conceptualize the effect of intrinsic and institutional characteristics on decisions regarding educators' teaching of ethics. Derivatives of this general model have been applied in a range of contexts (Astin, 1993; Finelli et al. 2012). More specific to research on university educators' teaching practices and perspectives, Lattuca and Stark (2009) developed the Academic Plan model through surveys and interviews with educators to understand course planning in higher education. The Academic Plan conceptualizes curriculum as having content, context, and form (which is analogous to input, environment, and output). Knight and colleagues (2016) applied the Academic Plan to understand how engineering academics make decisions regarding teaching and learning. The model 'frames teaching decisions as the result of a variety of complex interrelated forces ... both internal and external to their institution' (Knight et al., 2016, p. 696).

We applied the IEO framework to our study to understand how culture as an environmental variable affects ethics-related outputs including perceptions of sufficiency, topics, and broader perspectives. In an increasingly globalized market with companies and projects spanning countries, it is helpful to understand similarities and differences between societies. Input factors, such as discipline and gender, can also influence decisions regarding ethics teaching (Bielefeldt et al., 2018a, 2018b). To help isolate the effect of cultural environment, discipline and gender were controlled for in the analysis, as described in Methods. It should be noted that the institutional context where the educators themselves were trained was not included, only where they taught at the time of the survey.

Culture and Ethics

It has been asserted that 'cultural and ethical values are connected' and 'knowing a society's culture helps us to predict how ethics is valued in that society' (Alas, 2006, p. 239). Hofstede (1980, 2001) used survey data from IBM employees in over 70 countries to study culture and its role in business and management and grouped countries based on five dimensions: power distance, uncertainty avoidance, individualism, masculinity, and long-term orientation. The GLOBE study expanded on Hofstede's work (Venaik & Brewer, 2008), using empirical data, language, religion, geography, and historical accounts (House et al., 2004). Countries were clustered into 10 groups based on cultural practices ('as is') and values ('should be') of performance orientation, assertiveness, future orientation, humane orientation, institutional collectivism, in-group collectivism, gender egalitarianism, power distance, and uncertainty avoidance (Gupta, Hanges, & Dorfman, 2002). The current research utilizes the GLOBE clusters because they were developed based on more recent data and the humane orientation ('encourages and rewards individuals for being fair, altruistic, generous, caring and kind to others') aligns with ethics (Alas, Gao, & Carneiro, 2010).

We predicted differences in the ethics education of engineering and computing students among individuals teaching in countries from different GLOBE clusters based on the role that culture exerts on the environment. We focused on comparing the US to Anglo (excluding the US) and Western European (composed of the Germanic, Nordic, and Latin European) groups. A

Western European meta- cluster was used because of the overall similarity of its sub-groups. According to Gupta, Hanges, and Dorfman (2002), the Nordic and Germanic clusters are most similar and Germanic societies had a 0.4 probability of being classified as Nordic. Similarly, Israel was part of the GLOBE Latin Europe cluster but Hofstede grouped Israel into Germanic (Ronen & Shenkar, 1985), suggesting overlap between the clusters.

Educational Systems

The educational systems, historical practices, and normative contexts in which engineering operates vary across the cultural clusters, and these environmental factors may significantly impact ethics education. Background on these factors is presented to contextualize the three clusters and their connections between cultural norms and ethics education. In the US, professional societies and licensing have played a large role in engineering education, whereas in the United Kingdom (UK) there is more emphasis on learning-on-the-job (Brumsen, 2005). In the Netherlands, ‘engineer’ is an academic title with two types of degrees based on institution. Schools for Higher Professional education grant B.Eng. degrees with a four-year curriculum and technical universities grant M.Sc. degrees with a five- year curriculum (Brumsen, 2005). In Portugal, university education has an emphasis on scientific training, while polytechnic education has a vocational focus (Monteiro, Leite, & Rocha, 2017). The various institutional models and historical traditions influence the academic approach of engineering programs. Differences across the clusters are summarized in Table 23.

Table 23: Summary of differences across clusters

Cultural Cluster	US	Non-US Anglo^	Western Europe
Countries	US	UK, Australia, Canada, New Zealand, Ireland	Finland, Sweden, Denmark, Austria, Switzerland, Netherlands, Germany, Israel, Italy, Portugal, Spain, France, Norway*
Educational Approach	Individualistic, focused on moral autonomy	Emphasis on practical training	Interdisciplinary, focus on broader context, STS
Accreditation	ABET	Engineering Council, Engineers Australia, Engineers Canada, Engineering New Zealand Engineers Ireland,	National accrediting bodies align with ENAEE, a few ABET accredited programs
Professional Codes	Microethical focus	Macroethical emphasis on sustainability, environmental welfare	Blend of microethical and macroethical components
*Norway was not one of the countries included in the GLOBE analysis but was part of Hofstede's Nordic cluster			
^South Africa was excluded from the analysis since it is included in two GLOBE clusters			

Differences in Accreditation Bodies

Accrediting bodies exert significant influence on engineering education. Although the Washington Accord (International Engineering Alliance [IEA], 2017) acknowledges a common set of graduate attributes that promote the work of engineers across national borders, jurisdiction is left to individual accreditors to develop and assess specific program criteria. Ethical issues within the Washington Accord include a 'comprehension of the role of engineering in society' including 'the impacts of engineering activity: economic, social, cultural, environmental and sustainability' (WK7), design with 'societal and environmental considerations' (WA3), and 'ethics' (WA8) (IEA, 2013).

The Accreditation Board for Engineering and Technology (ABET) accredits programs in the US and 30 other countries, including Austria, Portugal, and Spain (ABET, 2017). The recent ABET update in 2017 seems to recognize macroethical issues in Criterion 3, outcome (5): '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, 2017). Previously, ethics (outcome f) and 'the impact of engineering solutions in a global, economic, environmental, and societal context' (outcome h) were separate (ABET, 2017).

Accreditation requirements in non-US Anglo countries vary. Canada includes design with 'environ- mental, cultural and societal considerations' and has robust macroethical criteria including 'sustainable design and development and environmental stewardship' and 'ethics and equity' (Canadian Engineering Accreditation Board, 2017). Criteria for accreditation in Australia includes 'social, cultural, ethical, legal, political, economic and environmental responsibilities as well as within the principles of sustain- able development' (Engineers Australia Accreditation Board, 2008). The UK accreditation (Engineering Council, 2014) requires design within the 'wider engineering context' and taking into account 'environ- mental and sustainability limitation' as well as 'economic, legal, social, ethical and environmental context' including the 'requirement for engineering activities to promote sustainable development.'

The European Network for Engineering Accreditation (ENAEE) was founded in 2006 to develop competency standards and recognition of degree programs in Europe (ENAEE, 2012). Its member organizations include France, Germany, Portugal, Italy, Denmark, Spain, Finland, and Switzer- land. Accredited programs, which earn the EUR-ACE label, must demonstrate that their Bachelor degree graduates attain an 'awareness of the wider multidisciplinary context of engineering', 'ability to consult and apply codes of practice and safety', 'awareness of non-technical ... implications of engineering practice', and 'ability to function effectively in a national and international context' (ENAEE, 2015). EUR-ACE accreditation is not compulsory and engineering programs may choose to be accredited by the agency within their country alone.

Professional Codes of Ethics

Professional societies influence ethics practices and perceptions by outlining the responsibilities of engineers in codes, potentially ‘bridging microethical and macroethical concerns’ by linking ‘professional and social ethics’ (Herkert, 2001, p. 405–406). In the US professional code of ethics, the six fundamental canons include no mention of sustainability, the environment, or impacts of engineering beyond the ‘welfare of the public’ (National Society of Professional Engineers [NSPE], 2018). In Section III, Professional Obligations, ‘engineers are encouraged to adhere to the principles of sustainable development in order to protect the environment for future generations.’ These macroethical responsibilities appear to be a lower priority due their placement and the less-strict language of ‘encouraged.’ Specific engineering disciplines embrace more macroethical issues in their individual codes (American Society of Civil Engineers [ASCE], 2019; Institute of Electrical and Electronics Engineers [IEEE], 2018b).

In contrast, the engineering codes of ethics of other Anglo countries have a greater focus on macroethical issues. In Canada, the code is explicit about the macroethical responsibilities to environ- mental protection, societal impacts, and social justice (Engineers Canada, 2016). In Australia, professional engineers must ‘respect the dignity of all persons’, ‘support and encourage diversity’, and ‘promote sustainability’ (Engineers Australia, 2010). Similar themes are found in the codes for New Zealand (Engineering New Zealand, 2016), the UK (Engineering Council, 2017), and Ireland (Engineers Ireland, 2017).

The codes of ethics in Western European countries have varying emphases on microethics versus macroethics. For example, the German Code (Verein Deutscher Ingenieure [VDI], 2018) includes microethics and also alludes to macroethical responsibilities such as awareness of technical systems in ‘social, economic and ecological contexts’, consideration of ‘environmental quality ... and social quality’ (2.1), and the primacy of ‘human justice’ and ‘human right’ in value conflicts (2.4). In the Netherlands, the Code of Ethics includes macroethical ideals of environmental concern, respect for cultural values, and promotion of diversity and inclusion (Het Koninklijk Instituut Van Ingenieurs [KIVI], 2018). The Swiss Society of Engineers and Architects states its ‘goal is a high-quality living environment that can meet future challenges and is designed to be sustainable’ (Schweizerischer Ingenieur und Architektenverein [SIA], 2018).

Differences in Educational Approaches

Global differences in educational systems, accreditation standards, and professional codes of ethics are manifested in diverse educational practices. Within the European Union, there are agreements to make degrees equivalent and a shared interdisciplinary approach to ethics as an integration of technology, philosophy, and social science (Zandvoort, van de Poel, & Brumsen, 2000). Most European countries conceive engineering ethics ‘as an interdisciplinary reflection at the crossroads of professional ethics, the human and social sciences, and the philosophy of technology’ which stands ‘in marked contrast with the situation in the United States’ (Didier, 2015, p. 87). The emphasis on licensing and professional societies in the US results in ethics education being intertwined with professional codes of ethics which focus predominately on microethics. However, ‘such codes are much less important in Europe than in North America’ (Didier, 2015, p. 89).

There are many reports in the literature on the integration of ethics into engineering courses and programs within the US (Haws, 2001; Herkert, 2000; Hess & Fore, 2017). Reports of engineering ethics education in other Anglo and Western European countries have focused on

Portugal (Monteiro et al., 2017), Australia (Bowden, 2010), New Zealand (Wareham, Takis Elefsiniotis, & Elms, 2006), Spain (Boni & Berjano, 2009), Denmark (Børsen, 2008), and the Netherlands (van de Poel, Zandvoort, & Brumsen 2001; Zandvoort, Van Hasselt, & Bonnet, 2008). However, this literature is largely descriptive without synthesis of ethics-related topics and educator perspectives about sufficiency. Furthermore, differences in ethics outputs based on cultural environment between US, non-US Anglo, and Western European institutions have not been quantified. The study presented in this paper was guided by the motivation to explore instructors' feedback on ethics education and delineate similarities and differences between educators at institutions in the three cultural groups.

Research Questions

The research questions were designed to test the hypothesis that cultural environment affects outputs related to ethics in engineering education.

RQ1: Do educators' perceptions of the sufficiency of ethics education of undergraduate and postgraduate engineering and computing students differ among those teaching in the US, non-US Anglo, and Western European countries?

RQ2: Are there differences in the ethics topics incorporated into courses taught to engineering and computing students among educators teaching in US, non-US Anglo, and Western European countries?

RQ3: What are educators' perspectives on the ethics education of engineering and computing students in the US, non-US Anglo, and Western European countries?

Methods

Surveys

All research was conducted in accordance with a protocol approved by the Institutional

Review Broad for Human Subjects Research. The data for this study were collected from three online surveys designed to explore how educators teach ethics. The surveys were developed based on a literature review, pilot testing, and user interviews at three institutions (Bielefeldt et al., 2016b). One survey focused on education in courses (with US- centric language), one survey focused on education in co-curricular settings (with US-centric language), and the third survey modified the course-focused survey to have more internationally inclusive language (e.g. 'postgraduate' instead of 'graduate'). The research questions explored in this work were based on questions included in all three surveys, as shown in Table 24. All three surveys concluded with demographic questions (Bielefeldt et al., 2018a). Although the authors believe that ethics education should encompass both micro- ethics and macroethics, interviews during the survey development and pilot testing found that US educators largely interpreted ethics to mean microethics and were unfamiliar with the term macro- ethics. Thus, survey language used 'societal impacts of technology' or 'broader impacts' to represent macroethics. For this paper, 'ethics' is inclusive of both domains.

Table 24: Survey items explored for each research question

Research Question	Survey Question	Response Options
RQ1: sufficiency	In your opinion, do engineering/computing students in your program receive sufficient education on the societal impacts of technology and ethical issues?	(1) yes, too much, the time could be better spent on other topics (2) yes, sufficient amount (3) a sufficient amount of ethics, but insufficient on the broader impacts of technology (4) a sufficient amount on the broader impacts of technology, but not enough ethics (5) no, not enough (6) unsure
RQ2: topics	Do you teach engineering and/or computing students about any of the following topics in any of your undergraduate and/or postgraduate courses? Check all that apply	18 named/described options listed, the option of 'other', and the option of 'none'

Research Question	Survey Question	Response Options
RQ3: perspectives	Please share your thoughts about the education of engineering/computing students regarding broader impacts and ethical issues	Open-response

A first survey campaign with invitations to the course-focused and co-curricular surveys in February-May 2016 was largely US-centric. Invitations to the course-focused survey were designed to intentionally sample ethics educators, such as distribution via email to members of the Engineering Ethics Division of the American Society for Engineering Education (ASEE). The survey invitation was also emailed directly to individuals who authored engineering ethics papers, including 404 US, 38 non- US Anglo, and 38 Western European authors. The co-curricular survey invitation was not intended to sample ethics educators; it was distributed to individuals primarily at US institutions who mentored co-curricular activities including student chapters of engineering and computing professional societies (e.g. American Society of Civil Engineers, Institute of Electrical and Electronics Engineers, Association of Computing Machinery), engineering honor societies (e.g. Tau Beta Pi, Chi Epsilon), engineering service groups (e.g. EWB-USA, Engineering World Health), engineering design competitions (e.g. Concrete Canoe), and undergraduate research experiences (e.g. REU). Additional details on survey distribution have been published (Bielefeldt et al., 2016b, 2018a).

Due to the low representation of respondents outside of the US, a second survey campaign was conducted in July to August 2018. To reach educators in non-US Anglo and Western European countries, the first and second author manually compiled contacts from institutions within these cultural clusters. For each non-US Anglo and Western European country, the top four to 10 institutions that appeared in the U.S. News and World Report Best

Global Universities Ranking (U.S. News & World Report, 2018) were included (n = 41 and 75, respectively). One additional institution from both Portugal and Spain were also included because their engineering programs are accredited by ABET. For each institution, one to three academic contacts were compiled for each engineering and computing disciplinary unit (faculty, department, or program). Targeted individuals within each disciplinary unit included those with leadership roles related to the department, program, education, or studies (e.g. head of studies, department head, dean, vice head of education, chair). This process was developed to reach educators actively teaching students in all engineering and computing related disciplines who also possessed a broader understanding of the education of students within their program. Educators were not specifically targeted for their involvement or interest in ethics based on their roles. This process generated 605 contacts from non-US Anglo institutions and 615 from Western European institutions that were personally sent a link to the online survey. A question near the end of the survey allowed respondents to provide the names and/or email addresses of other engineering and computing educators that our research team should contact. Through this snowball sampling of ethics educators, an additional 27 non-US Anglo and 14 Western European educators were invited to take the survey.

Respondents

In the first survey campaign, 1359 at least partially complete responses were collected from educators in the US representing 375 institutions and all 50 states. The surveys also generated 25 responses from non-US Anglo countries and 14 responses from Western European countries. There was a 21% response rate to the co-curricular survey and 8%–28% response rate for the curricular survey (Bielefeldt et al., 2018a). The exact number of unique individuals who received the curricular survey link is unknown since people could receive the invitation via their participation in multiple ASEE divisions and their publication of engineering ethics-related research. In the second survey campaign, an additional 99 survey responses from non-US Anglo (15.7% response rate) and 75 from Western European countries (11.9% response rate) were collected. Table 25 details the countries that are included in the non-US Anglo and Western Europe groups from the two survey campaigns and the number of survey respondents from each country.

Table 25: Respondents from non-US Anglo and Western Europe clusters

Non-US Anglo	n	Western Europe	n
Australia	49	Austria	1
Canada	41	Germany	5
UK	17	the Netherlands	13
Ireland	5	Switzerland	1
New Zealand	12	Denmark	4
		Finland	3
		Sweden	11
		Norway	5
		France	5
		Israel	1
		Italy	10
		Portugal	14
		Spain	16

Analysis: Comparison Across Groups

To test our hypothesis that culture influences ethics teaching outputs, we needed to account for confounding differences among the response groups, in both demographics and response numbers. Previous explorations of the US-dominated data from the first survey campaign found that responses differed among the course-focused and co-curricular survey respondents (presumably due to intentional sampling of ethics educators for the course survey; Bielefeldt et al., 2016a), among engineering disciplines (Bielefeldt et al., 2016a, 2018b), and with gender (Bielefeldt et al., 2018a). Given these challenges, a matching strategy (Stuart, 2010) was used to select from among the large group of US respondents a numerically and demographically similar comparator for the non-US Anglo respondents and Western Europe respondents. For all of the US respondents who met the given criteria, a random number generator was used to select individuals for the comparator group. Separate comparator groups of US respondents were created for the non-US Anglo and Western Europe clusters due to the unique characteristics of the respondents within each cluster. For research question 1 (sufficiency perceptions), all non-US Anglo and Western European respondents who answered that survey item were included in their respective samples. For research question 2 (topics), only educators who taught at least one topic were included. More detail on the statistically matched sampling process including demographics and relevant covariates of the respondents is available in Appendix K.

Statistical tests were conducted in IBM SPSS Statistics 24 to compare the non-US Anglo to its matched sample and the Western Europe to its match US sample. Fisher's exact tests were used to determine statistically significant differences between the samples because this test is more accurate for small sample sizes (McDonald, 2014). Statistically significant differences were noted when the two-tailed p values from the Fisher's exact test were 0.05 or lower.

Survey Qualitative Analysis

To explore research question 3, the open-ended survey question generated responses from 318 US, 45 non-US Anglo, and 19 Western European educators. The responses were analyzed using emergent, thematic coding (Creswell, 2012). A codebook and inter-rater reliability among three coders were established based on responses from the first survey campaign (details in Canney et al., 2017 and Appendix L). The first author participated in coding the first group and then coded all of the responses from the second campaign. Themes and illustrative quotes are provided to add richness to the quantitative findings.

Results and Discussion

RQ1: Perceptions of Sufficiency

The percentage of respondents who believed that undergraduate and postgraduate engineering and computing students in their programs received insufficient education on the societal impacts of technology and ethical issues are shown in Table 26.

Table 26: Percentage of respondents in each group who rate students' exposure as insufficient

	Non-US Anglo	US/Anglo Comparator	Western Europe	US/W.Euro Comparator
Undergraduate, n	*105*		*67*	
Insufficient ethics	54	52	66	52
Insufficient broader impacts	58	55	48	55
Postgraduate, n	*85*		*66*	
Insufficient ethics	84	76	68	76
Insufficient broader impacts	81	81	58*	77
			*p<0.05 for US comparator	

About half of the respondents from non-US Anglo countries believe that undergraduate students in their program are not receiving enough ethics instruction; the matched US sample was similar based on the Fisher's exact test and two-sided exact significance of $p = 0.89$. A similar percentage of non-US Anglo indicated that the education of undergraduate students related to broader impacts is not sufficient; respondents in the matched US sample voiced a comparable opinion ($p = 0.78$). The results indicate educators perceive room for improvement across ethics and societal impacts in both clusters.

Almost two-thirds of the educators in the Western Europe sample reported that undergraduate students in their program did not receive a sufficient amount of ethics education. Approximately half believed that the broader impacts education in their program is sufficient.

This result is congruent with the emphases noted in educational approaches within this cluster (Zandvoort, van de Poel, & Brumsen, 2000) including broader coverage of the impacts of engineering and technology and less focus on traditionally microethical conceptions of ethics. The matched US sample indicated the opposite trend where more respondents were satisfied with the ethics than broader impacts education of their undergraduate students. This finding aligns with the microethical focus traditionally associated with US engineering programs (Herkert, 2005).

The results indicate widespread dissatisfaction with the education of postgraduate students on these topics across all of the clusters. Only 16% of the non-US Anglo educators reported that post- graduate students receive enough ethics education and 19% rated the broader impacts instruction in their program as sufficient. These findings were comparable in the matched US sample. As with undergraduate education, approximately two-thirds of the respondents in the Western Europe sample reported ethics education in their program is insufficient. However, compared to their matched US sample, a statistically significant higher percentage noted that broader impacts education is sufficient (although still the minority). These results suggest the need to better integrate ethics and broader impacts into postgraduate coursework. Without accreditation mandating these topics at the postgraduate level, there may be less pressure or incentive to include them. As a result, it is up to individual educators to fill these gaps and ensure that engineers entering academia and industry have an understanding of their ethical and societal responsibility.

RQ2: Ethics-related Topics

The survey asked educators to indicate which topics they teach (among 18 options, other, and none) in any of their courses to understand the context in which ethics are being taught to engineering and computing students. Table 27 displays the percentages of educators in each group who reported teaching each ethics-related topic.

Table 27: Percentage of respondents in the groups who indicated teaching each ethics-related topic

Ethics-related topics	*All US*	*non-US Anglo*	*US/Anglo Comparator*	*Western Europe*	*US/W.Euro Comparator*
n	*1209*	*107*	*107*	*68*	*68*
Professional practice issues	60	83*	60	51	59
Societal impacts of technology	54	64	50	54	51
Engineering decisions under uncertainty	49	60	48	41	54
Safety	48	59	62	38*	57
Engineering code of ethics	46	54	45	26*	46
Sustainability/sustainable development	44	67*	35	66*	43
Ethical failures/disasters	44	44	47	21	37
Ethics in design	39	42	40	28*	46
Risk and liability	36	49*	30	29	29
Environmental protection issues	35	39*	24	51*	32
Responsible conduct of research	33	45	33	41	31
Ethical theories	22	27	25	16	28
Social justice	18	20	15	12	21
Engineering and poverty	15	21	15	12	21
Privacy and civil liberties	13	13	19	16	18
War, peace, military applications of engineering	9	10	15	3	6
Other	9	14	7	9	6
Bioethics	8	6	2	6	4
Nanotechnology	4	1	6	3	4

*p<0.05 for US comparator

The most commonly taught topics for the respondents at institutions in the non-US Anglo group (in order of decreasing preference) were professional practice issues, sustainability, societal impacts of technology, and engineering decisions under uncertainty. The most commonly selected topics for the respondents in the Western Europe group (again, in the order of decreasing preference) were sustainability, societal impacts of technology, professional practice issues, and environmental protection issues. Non-US Anglo respondents taught a median of 7 topics, the matched US educators taught 4 (a statistically significant difference, $p < 0.05$); Western Europe respondents taught a median of 4 topics and their matched US educators also taught 4 topics.

A higher percentage of non-US Anglo respondents taught environmental protection, professional practice issues, risk, and sustainability than matched US respondents. These findings could be attributed to the external forces (accreditation bodies and professional societies) exerted on institutional environments (the cultural context) in shaping decisions about ethics teaching. Accreditation in Canada, Australia, and UK explicitly mandates that students learn about sustainable development. Non-US Anglo accreditation bodies also put more of an impetus on environmental protection.

Educators at institutions in Western Europe indicated teaching sustainability and environmental protection issues at higher frequencies than the US comparators. The US comparators reported teaching engineering codes of ethics, safety, and ethics in design significantly more than the Western Europe respondents. This finding aligns with the greater focus on professional codes in the US than in Western Europe (Didier, 2015). It is worth noting intra-group variations between Nordic/Germanic ($n = 33$) and Latin Europe ($n = 35$) for eight topics. For example, 73% of the Nordic/Germanic educators taught societal impacts compared to 37% of the Latin Europeans, 45% taught ethics in design com- pared to 11%, and 61% taught responsible conduct of research compared to 23%. These differences suggest a potential limitation in analyzing the two groups as one cluster. However, the Nordic/Germanic and Latin Europe groups were not matched on any covariates so different disciplines, genders, and survey types could bias the results. For more information on the topic differences between the Nordic/ Germanic and Latin Europe groups, please see the Appendix M.

The differences between the US comparison groups for the non-US Anglo and Western Europe groups illustrate the important role that demographic factors and sampling strategies play in the integration of ethics-related topics. The two US comparison groups, with different disciplinary and gender compositions, varied in their prevalence of topics indicating that cultural environment is one influence on teaching but those practices are also affected by a range of inputs.

RQ3: Broad Perspectives

Themes from the open-ended responses that related to challenges and goals/potential and were the most prevalent across the three culture groups are discussed below.

Challenges

One challenge associated with ethics education is that it is sometimes taught separately from technical content or in a way that makes it difficult for students to make the connection. One educator at a US institution noted,

> It seems to me that many engineering students (like faculty) still see ethics and broader impacts as outside 'real' engineering. This fundamental problem seems to be cultivated by conventional engineering education and the profession at large.

This socio/technical dualism (Cech, 2014) influences the students' understanding of their role as engineers, which can be problematic if they do not learn to reflect on the social and ethical implications of their work. An educator at a non-US Anglo institution noted:

> Engineering programs are conceptualized as mainly technical programs with some social add-ons. This needs to change and engineering needs to be understood better as a social and technical activity.

To address the challenges of separating social and ethical issues from technical material, the vice dean of education at a non-US Anglo institution described how his undergraduate program was redesigned

> ...to make the societal impact of engineering/computing central to the learning and integrated into a spine of project based activities. The development of this thinking and skills does not work if separated from the core material or if it is not given explicit relevance to the technical and practical application of the subject.

Projects offer opportunities to organically integrate the many facets of engineering problems, which can demonstrate the relevance in an engaging learning application.

A second challenge represented across the three samples is the difficulty in covering ethics education in an already full curriculum. An educator at a US institution commented,

> The most significant issue that I encounter with teaching students about ethical and professional issues and broader impacts is making space for this in an already packed curriculum. This is becoming even more problematic due to pressure from the university to pare back the required credits for engineering majors.

This challenge is not unique to the US; a respondent in the non-US Anglo cluster noted, "the syllabus in many areas of engineering education has been eroded and to make room for discussing ethics and societal impacts in the limited available hours is very challenging." An educator in the Western Europe cluster described engineering courses as "very dense" and suggested "parallel development" without detracting from technical content. Responses suggest that ethics and broader impacts education is insufficient because they are given superficial importance that is not prioritized when external forces pressure programs to reduce the credit hours of engineering degrees.

A third challenge was that students and/or colleagues do not care about ethics education. An educator at a US institution commented,

> The teaching of broader impacts and ethical issues always requires a 'champion' faculty in the department. Not all faculty are on board with teaching this information, given the amount of fundamental engineering concepts that need to be covered.

A non-US Anglo respondent noted that "very few staff are keen to teach this topic" while another commented that "it is generally hard to staff ethics & society material." In addition to a lack of support and interest from other educators, a lack of student engagement in engineering ethics has been noted as a challenge to its effective inclusion in the curriculum (Newberry, 2004; Polmear et al., 2018). A respondent from a US institution noted, "I've almost never seen an engineering student interested in this topic." A non-US Anglo educator commented that the lack of engagement may arise because "students don't see it as relevant to getting a job and so don't take it seriously. This material is perceived as 'fluff'." A Western European respondent described a similar challenge in noting, "it is very hard to interest mechanical engineering students for anything that is not about technology or engineering." The perceived lack of student engagement may further inhibit educators' motivation to integrate these topics (Newberry, 2004).

Goals/Potential

Some survey respondents discussed goals and potential for ethics education. Educators across all three samples expressed the importance of ethics education in engineering and computing. One educator in the US noted that ethics and broader impacts "deserve more attention than it receives now" and will continue "growing in importance." Another US respondent stated "we spend a lot of time building things ... because we can and not because we should." An educator from a non-US Anglo institution expressed a similar perception of the role of engineers as "responsible citizens", which "requires them to understand and form their own opinion of the broader/ethical impacts of their role." Not only does this education and reflection strengthen future engineers' public imperative, it also increases the relevance of the engineering material and students' engagement with it. An educator at a Western European institution expressed that regardless of the career trajectory of engineering graduates, education on these topics can help mitigate ethical mistakes after graduation by increasing awareness: "sometimes young professionals do wrong things simply because they do not know they are not ethically incorrect."

Respondents expressed several specific points in engineering education that can be improved to better prepare graduates for issues they may face. An educator in the non-US Anglo cluster stated "I don't feel that our educational systems are keeping pace" with the ethical and societal issues embedded in computing. Educators should integrate issues that are topical and relevant, such as unmanned aircraft systems (NAE, 2018), autonomous systems (IEEE, 2018a), and nanotechnology (Abuelma'atti, 2009).

Another theme that was represented across the three groups was the recommendation to integrate ethics and broader impacts into existing courses. Teaching these topics in dedicated courses, often offered in humanities or social sciences departments, can risk implying that ethical and societal issues are peripheral to engineering (Herkert, 2000). A US educator expressed that ethics education "is best served by incorporating it as a core component of existing classes – not separating it as a separate add-on topic." A respondent from a non-US Anglo institution voiced a similar sentiment.

> Typically these issues are introduced as stand-alone modules in broader courses or covered in a specific, dedicated course. The courses are rarely taught by people with professional exposure to these issues ... I strongly believe that this education needs to be integrated throughout the curriculum, not approached in a 'bolt-on' fashion in limited courses ...

Infusing these topics into engineering courses will foster students' engagement. An educator in the Western Europe sample encapsulated the value of the intentional and incremental integration of ethics and broader impacts.

> Education should be given step-wise, i.e. when entering into the under-graduate programs, before the B.Sc. thesis, before the M.Sc. thesis, in the beginning of doctoral studies and after finalizing them ...

The open-ended responses provided insights into the challenges that engineering and computer educators face in teaching students about ethics and broader impacts and their goals for the continued development of this subject in the curricula.

Limitations

One limitation of this study is that the data is based on individuals who selected to participate in the survey. The survey invitation and consent information indicated that the study was focused on engineering ethics and thus educators who do not teach these topics, nor believe that they should be taught, might not have participated. As a result, the respondents might not be representative of the entire engineering education community. Only 11% of the US, 12% non-US Anglo, and 24% Western Europe respondents indicated that they do not teach any ethics-related topics in their courses. Individuals who perceive ethics education as outside the technical focus of the curriculum, beyond their expertise, and/or oppose some elements of ethics education (Leef, 2017; Newberry, 2004) may not have participated in the survey.

A second limitation is the imbalance between the respondents at US, non-US Anglo, and Western European institutions. Survey distribution more explicitly targeted individuals in the US (n$\sim$5000 for the first campaign) compared to non-US Anglo and Western European countries (n$\sim$1220 for the second campaign). Given the relatively small number of non-US Anglo and Western Europe respondents, these clusters cannot be further disaggregated, which would provide more opportunity to evaluate ethics-related teaching practices and perceptions across cultures and national borders. Finally, the solicitation and survey were conducted in English, which may have also limited the ability of potential respondents to participate in many countries. Future research could address these issues.

Conclusions

The survey results provide insight into how educators at institutions in the US, non-US Anglo countries, and Western European countries incorporate ethics into their courses. The results of this exploratory study suggest the influence of environment, conceived as cultural clusters, on output, in the form of sufficiency perceptions, ethics-related topics, and broad perspectives, when controlling various input covariates. The results suggest that non-US Anglo educators more frequently integrate macroethics topics; e.g. environmental protection issues, sustainability, professional practice issues, and risk, compared to the matched US group. Accreditation criteria and professional codes in Canada, the UK, Ireland, New Zealand, and Australia place greater emphasis on these topics, suggesting the influence of these environmental forces on instructional practices. Educators in the Western European group also taught environmental protection issues and sustainability more than respondents in the matched US group but reported including codes of ethics, ethics in design, and safety in their courses less frequently than the matched US group.

Ratings of sufficiency suggested the need to increase the amount of ethics and broader impacts education across the cultural clusters. At the undergraduate level, about half of non-US Anglo educators and their matched US respondents rated ethics insufficient (54% and 52%, respectively) and broader impacts as insufficient (58% and 55%, respectively). Approximately two-thirds of the Western European educators reported broader impacts education is insufficient. Across all of the clusters, results indicated the need to improve the ethics and broader impacts education of postgraduate students. There was a statistically significant difference between Western European educators and their matched US respondents in terms of perceptions of the amount of broader impacts. Countries in Western Europe, such as the Netherlands, have deviated from the 'traditional American approach' of focusing on codes and microethics to 'pay more systematic attention to the context' and broaden the scope of engineering ethics (van de Poel, Zandvoort, & Brumsen, 2001, p. 269). This curricular design reflects a greater emphasis on broader impacts and supports the influence of environment on teaching practices.

Open-ended responses reinforced an interest in improving students' exposure to, and under- standing, of these topics. These data suggest patterns of challenges and opportunities related to macroethics education that transcend the cultural differences. The widespread perceived lack of sufficiency in ethics education also informs the need to share best practices across cultures.

People from different countries and cultures solve and define problems in unique ways, necessitating the need for global competency in engineering education (Downey et al., 2006). Understanding how engineers are trained and the exposure they receive to different topics can increase awareness and enhance collaboration in a globalized profession. Clustering offers a means to understand how 'cultural environment systematically influences' behaviors and attitudes of people within different countries (Ronen & Shenkar, 1985, p. 435). This environmental influence coupled with a suite of inter- related inputs affects educators' decisions regarding what and how to teach. By attempting to isolate the cultural cluster, this exploratory work sought to understand the effect of environment on ethics education outputs. Globalization has enabled technology, communication, and infrastructure to connect the world and has made the engineering workforce more internationally diverse and mobile (Downey & Lucena, 2005). This internationalization of engineering practice warrants a consideration of how engineering students are being educated across cultures and what similarities and differences define ethics outputs in Anglo and Western European countries.

Chapter VII: Conclusion

Summary

My dissertation examined internal, environmental, and cultural influences on engineering educators' practices and perspectives related to ESI education. This study was motivated by the national and global call to improve the ethical development of engineering students (NAE, 2017) and the dearth of research in this area. One of the primary levers in the integration of ESI in curricula is the engagement of engineering faculty. Engineering educators have the greatest access to students in the dense technical curriculum; serve as the link between education and practice; and shape educational priorities at the broad scale and within their own classrooms. For these reasons, engineering faculty are well positioned to disrupt the "culture of disengagement" in engineering (Cech, 2014) and demonstrate that ESI is integral to what it means to do good engineering. However, the minority of engineering faculty teach ESI and related topics in their courses (Romkey, 2015). As a result, it is important to understand how faculty arrive at their decisions regarding course planning. Educators operate in a complex context that is shaped by personal, environmental, and curricular variables. Untangling these different influences can elucidate how to better support faculty members' ESI instruction thereby improving students' ethical awareness, reasoning, and behavior (Finelli et al., 2012).

My research was structured to peel back a different layer of the Academic Plan model in each chapter. Chapter IV examined internal influences at the level of individual educators. The case study research used in-depth interviews with nine engineering faculty to identify experiences and beliefs that influenced their teaching of ESI. The qualitative analysis revealed four themes related to internal influences. The Personal theme pertained to beliefs, interests, motivations, faith, and family. The Academic theme included the training and international experiences that the participants engaged in as undergraduate or graduate students. The Professional Experience theme included influences from time in industry, military, and international work. Finally, the Professional Development theme encompassed formal training, community of support, mentor, and change in research/scholarship. These results provided more granularity to the Academic Plan model by illuminating internal influences of significance to engineering educators in ESI course planning.

Chapter V employed a case study methodology to explore the influence of the academic environment on educators' ESI practices and perspectives. Environment can influence course planning explicitly through curriculum requirements and structural policies and implicitly via the culture experienced by faculty within it. The two cases were selected based on initial faculty interviews; Case A was described as supportive of ESI education and Case B as resistant. Data were collected from additional faculty interviews, faculty surveys, and online documents to explore the impact of environment and understand if there were structural or personal differences between the cases that accounted for the divergent cultures. Results indicated that department has the most acute environmental effect on educators' course planning and the culture they experience relative to it. Administrators (chairs and heads) and policies (promotion and tenure) can exercise significant influence by setting the tone and establishing the values of the department.

Chapter VI took a broader view of environment by examining the influence of culture on educators' ESI instruction. The study was designed to test the hypothesis that cultural environment, conceptualized as clusters, affects ESI education outcomes related to perceptions of sufficiency, topics, and perspectives. Culture can manifest in education systems, accrediting bodies, professional codes of ethics, and educational approaches; all of these forces shape the context in which ESI teaching is developed and implemented. Survey responses from educators at institutions in the US, non-US Anglo, and Western Europe clusters were compared after accounting for covariates to better isolate the effect of culture. The results suggested the need to increase students' exposure to ESI across the clusters, especially at the post-graduate level. The survey responses indicated that non-US Anglo educators more frequently teach macroethical topics, such as environmental protection issues and sustainability, than their US counterparts. This emphasis is reflected in the professional organizations and accrediting bodies in Canada, the United Kingdom, Ireland, New Zealand, and Australia. Educators in Western Europe also reported integrating these topics more than US educators but taught codes of ethics, ethics in design, and safety less frequently.

The results across the three chapters were synthesized to inform a modified Academic Plan model, Figure 3.

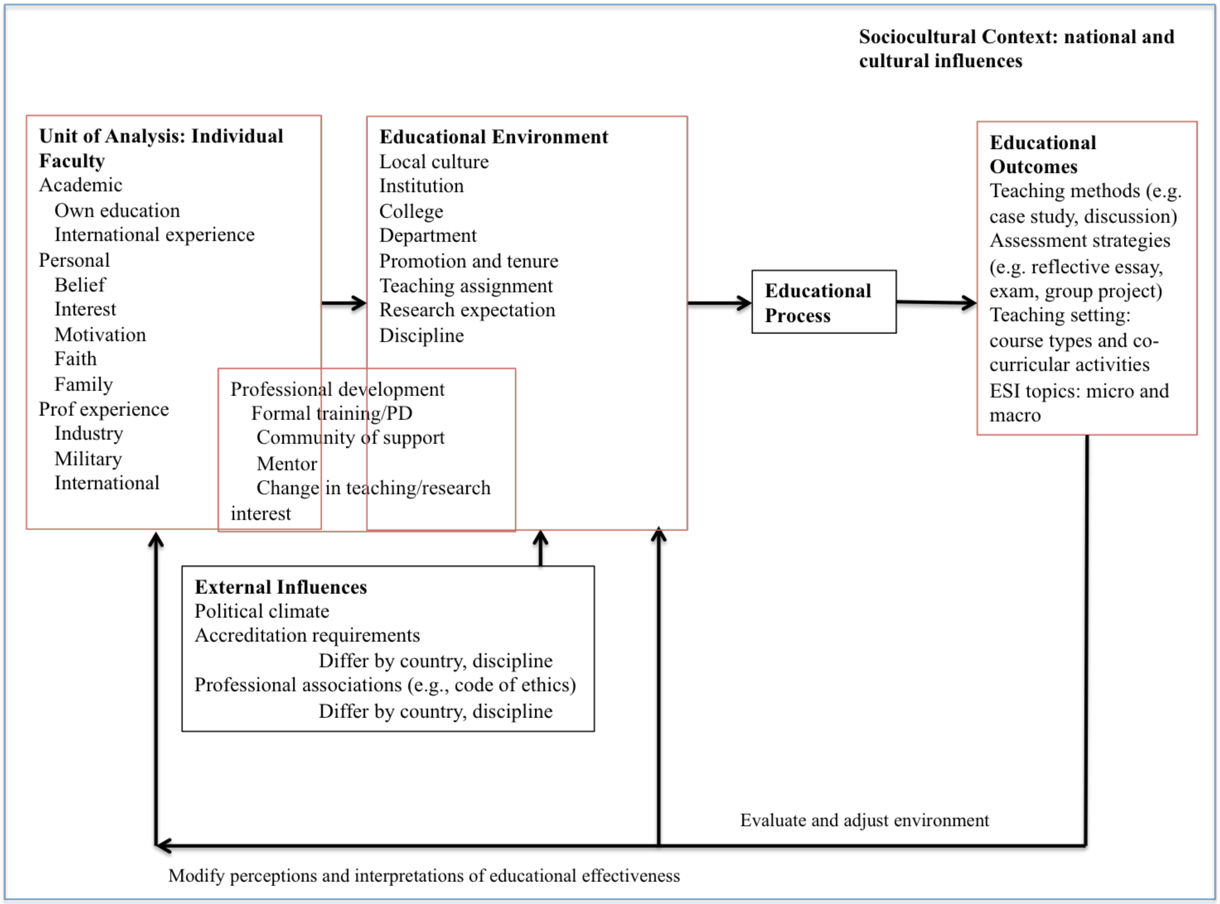

Figure 3: Modified Academic Plan model

Implications

The results reinforced the influence of personal, environmental, and cultural factors on course planning in higher education that have been reported previously (Katz & Knight, 2017; Knight et al., 2016; Lattuca & Stark, 2009). My research also made novel contributions to our understanding of the relationship between influences on teaching decisions, engineering faculty, and ESI education outcomes. The implications of this work are summarized below.

- Although engineering programs cannot change what educators bring to the job, such as their personal beliefs and previous experiences, they can leverage those factors through hiring practices and professional development opportunities. Understanding influences on educators' ESI instruction and being intentional about hiring people with diverse backgrounds and perspectives can broaden students' insight into ethical and societal issues through a variety of lenses.

- Personal interests, beliefs, and experiences can be powerful influences. Educators should be encouraged to reflect on their internal influences to find a personal and authentic way to bring ESI into their classrooms.
- Granting educators the autonomy to teach from their own vantage point can increase their motivation to teach ESI. Macroethics includes a range of topics that is relevant to all disciplines and subjects. This broad conceptualization of engineering ethics enables faculty to draw on their own internal influences to provide greater value and relevance, which can then increase students' motivation (Vanasupa et al., 2012).
- Awareness and intentionality in hiring practices can help a department or college to build a culture that is supportive of ESI education from the ground up. Explicit encouragement from those in leadership roles to integrate ESI, and support the faculty who do so, can bolster this culture.
- It is important to have structures and policies that reflect the espoused values of the environment (department, college, and institution). It is not enough to say that a program values the ethical development of students if faculty who work to foster ethical development are not supported in evaluation, promotion, and tenure reviews. The criteria in these processes can serve as a barrier or enabler of ESI education.
- Individual motivation and interest can be powerful levers but programs cannot rely on faculty initiative alone. A purely bottom-up approach can create ad hoc coverage of ESI instead of the intentional integration across the curriculum, which has been proposed as

the most effective model for ethical development (Colby & Sullivan, 2008; Hess & Fore, 2017; Li & Fu, 2010).

- With the mobilization and diversification of the engineering workforce, it is important to understand how students across national and cultural boundaries are educated about ESI. Cultural forces can shape differing priorities and perspectives for educators at institutions in different clusters.
- The US is lagging behind non-US Anglo and Western Europe countries in teaching environmental protection and sustainability to engineering students. These issues are of global importance so there is a need to expand macroethics in the US to ensure that our students are competitive with their international peers and that the next generation designs and builds with a sense of societal and environmental responsibility.
- Professional codes of ethics are regarded differently outside of the US. The narrow conceptualization of ethics in terms of codes can impede future engineers' ability to work across cultural boundaries and with others who define ethics differently.
- Without accreditation, post-graduate education can lack an impetus to formally and systematically integrate ESI. As a result, programs need to rely on internal instead of external forces to drive the integration of ESI in curricula for post-graduate students.

Future Work

This exploratory work has opened the door to additional paths of inquiry. Opportunities for future research to build on the findings encapsulated in my dissertation are provided below.

- There are opportunities to explore the temporal development of educators' interest in, and instruction of, ESI in engineering. In several interviews, faculty described pivots in their scholarship and research that were catalyzed by personal and professional experiences. Although it was not the focus of the current study, it would be interesting to explore the trajectory of ESI engagement. One limitation of the Academic Plan model is it does not convey the intersectionality and timing of influences on course planning so future work could examine these relationships.

- One limitation of the academic environment case study, explored in Chapter V, was that the departments represented different disciplines. As a result, it was challenging to untangle the effect of disciplinary versus departmental culture. Future research could explicitly address this concern by including departments of the same discipline across multiple institutions as case studies.
- The study of cultural clusters, Chapter V1, could be expanded to include interviews. This approach would provide deeper insight into the cultural factors that are most influential. Culture is a broad umbrella and studying it at the current level did not enable me to parse or weigh different influences such as the relative importance of accreditation requirements, historical practices, and normative contexts.
- The exploration of cultural environment could be expanded to other GLOBE clusters such as Confucian Asia and Southern Asia due to the prominent role of the countries within these clusters in global technology development and the size of their engineering populations. The National Science Board (2018) reports that China and India awarded the most degrees in science and engineering in 2014, the most recent year that data were available. Furthermore, over half of the university degrees awarded in Japan, China, and Iran were in science and engineering. Due

to the number of engineering students being educated in these countries, it would be interesting to explore the ESI practices and perspectives of engineering faculty within them.

- Cultural clusters group countries on a host of criteria that convey similarities between societies. However, cultural differences between countries within the same cluster persist and could be explored in future research. A larger survey dissemination that would enable quantitative analysis at the country level or interviews with educators from different countries could explore the influence of national culture. Downey and Lucena (2005) alluded to the differing perceptions of engineers, which sparked an interest in a more narrow scope of culture.

> French engineers have tended to value mathematical theory and aspire to work in government where they constitute the highest-ranked occupation in the country, British engineers have tended to value craftsmanship and work in the private sector where they constitute a relatively low-ranked occupation. German engineers have exhibited yet another pattern, having attained the status of highly-valued workers only after German unification in 1870 and then later becoming model German citizens through their commitment to precise, high-quality techniques. Because Britain and France had extensive colonial networks, one can travel around the world today and find countries with unique mixes of influences on engineers from both colonial and domestic sources. The USA, as a former colony of Great Britain and early ally of France, developed an unusual commitment to a 'balance' between practical and theoretical knowledge, with a

> pendulum that swings back and forth depending upon the dominance of images characterizing the most immediate threats to future 'progress'. (p. 256-257)

- Future work could be expanded to include students in the Academic Plan framework. First, research could examine if there are differential impacts on student learning based on the influences that shaped an educator's course planning. For example, what impact does teaching from an industry perspective have on students' outcomes? What impact does an educator have when her instruction is motivated by personal experience and interest in international service work? Are students attuned to the culture experienced by faculty related to ESI education? If so, do these implicit values shape their perception of the value and relevance of ESI? A second opportunity for further consideration is the role that students play in course planning via the Academic Plan. There is a feedback process between educational outcomes and environment through evaluation and adjustment that could be explored.

Conclusion

Deconstructing the Academic Plan enabled me scope three distinct but interconnected explorations of influences on faculty's ESI practices and perspectives. Synthesizing results across the three chapters provided a more nuanced derivation of the model that is specific to ESI education in engineering. The power of this framework is its way of knitting all of the threads together.

Although engineering faculty face a number of curricular and structural challenges in ESI education and may feel unprepared to teach these topics, this research illuminated a range of entry points into the conversation and a number of ways that they can be supported in their environment.

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Appendix

A. Copy of interview protocols used for Chapter IV

Round 2 Interview

#	Question	n
1.	What do you view is the role in society of engineers and/or computer scientists?	4
2.	Describe what has influenced your current efforts to educate engineering and computing students about ethical and societal issues.	7
2.1	To what extent did you feel adequately prepared to teach students about ethical and societal issues?	2
2.2	Have you engaged in any professional development around these topics? Such as attending workshops or reading literature?	1
2.3	To what extent is ABET and accreditation a factor?	2
2.4	To what extent was your own education as a student influential?	4
2.5	Was time in industry influential?	2
2.6	Has your own service or humanitarian work been impactful?	
2.7	Do your personal religious values play a role?	
3.	What if any ethical theories form the foundation of your ethics instructional practices?	2
3.1	If no explicit theories, what guided the development of your ethics-related instruction?	
4.	To what extent do you feel that engineering and/or computing students are interested in ethical issues and perceive that they are important? Societal impact issues?	5
4.1	Have you ever felt student resistance?	2
4.2	Do you feel that students have differential interest in certain topics or pedagogies?	1
4.3	Have you perceived any differences among students – such as among different majors, ranks (first-year vs. seniors vs. graduate students), gender, etc.?	1
5.	How do you assess the outcomes of your teaching practices around ethics and societal impacts?	3
6.	To what extent do you feel that your efforts to educate engineering and/or computing students about ethics and societal impact issues are integrated within a cohesive curricular plan?	6
6.1	Do you integrate ethical/societal issues to some extent into all of the courses that you teach?	1
6.2	Are your practices part of ethics across the curriculum?	3

6.3	Do you work with others to intentionally build various ethics/societal impact (ESI) topics and skills into the education of students in XX engineering/CS?	1
7.	In what ways do you perceive that your priorities for educating engineering and computing students about ethical and societal issues are similar to and differ from colleagues in your department?	2
7.1	In your college?	
7.2	At your institution?	3
8.	Is there anything else you would like to add?	4

Round 1 Interview

#	Question	n
1.	Tell me about the course that you teach that you believe is most effective in facilitating ethical development in your students.	1
2.	What pedagogical approaches do you use in this course and how do you think they work?	1
3.	What makes you believe that this approach is effective?	
4.	What were your motivations and goals in developing this course?	1
5.	What is your understanding of macroethics and how it is distinguished from microethics in engineering?	
6.	What challenges have you encountered in incorporating macroethical topics? With respect to students? Other faculty? Department?	1
7.	Do you perceive students as being interested in the topics that you cover in this activity? If so, are there certain topics that tend to interest students more than others?	
8.	Have you ever had a student share about or seem to experience an internal conflict or struggle with respect to a topic?	
9.	What about your course do you think could be easily transferred to other programs or contexts? What do you think are challenges or barriers to the transferability of your exercise/project/class?	1
10.	How would you describe the culture at your institution in regards to the macroethics education of engineering and computing students?	1
11.	Do you feel supported by your department/school in your teaching of macroethics?	
12.	Can you describe how your experience in industry as a professional engineer has impacted your teaching of macroethics?	1
13.	Is there anything else that you would like to share that I have not asked about?	1

Department Colleague Interview

#	Question	n
1.	How would you describe the culture at your institution in regards to the education of engineering and computing students on ethics and societal impact issues?	1
1.1	Have you noticed changes over time?	1

1.2	How does the culture compare to other institutions at which you have taught?	1
2.	Are ethics and societal impacts integrated throughout the curriculum?	1
2.1	Are multiple faculty encouraged to integrate these topics into their course?	1
2.2	Can you explain the reasoning behind having engineering faculty teach ESI instead of having faculty outside of engineering teach ESI?	1
3.	How have your professional experiences been influential in your interest in teaching ethics?	1
4.	Have you ever had a student share about or seem to experience an internal conflict or struggle with respect to a topic?	1

B. Example of member check for Chapter IV

The member check is intended to improve the reliability of our qualitative research. This process allows me to check my interpretation of our interview and how it fits within the framework.

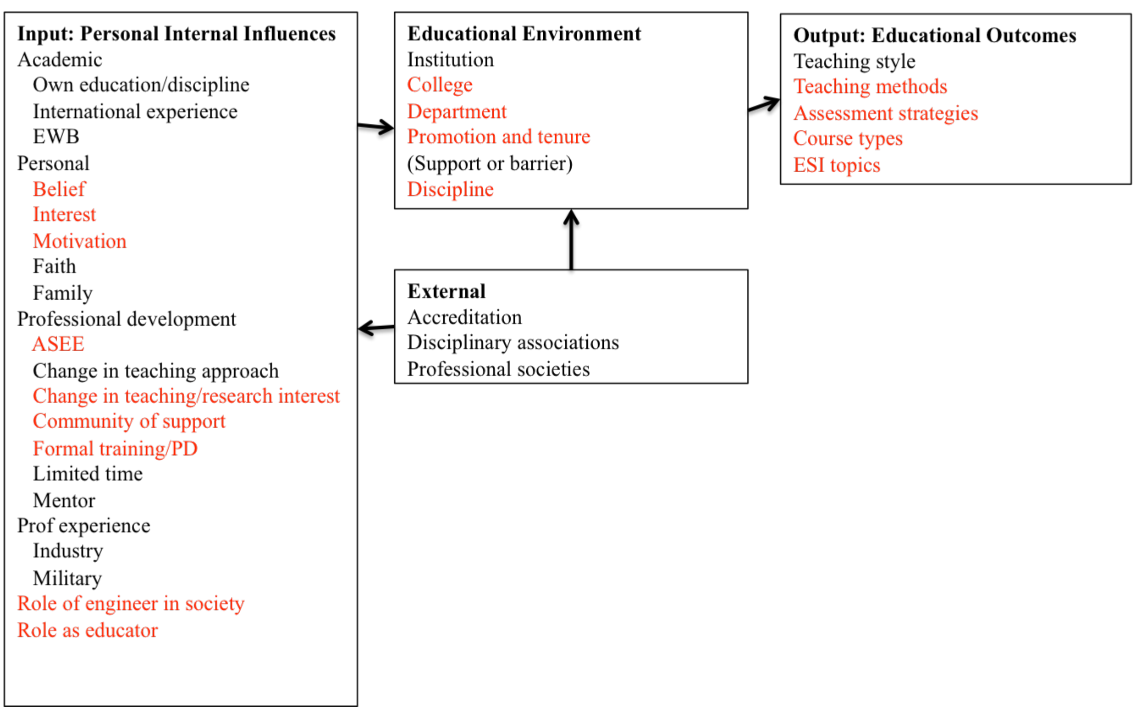
Input is the current focus but preliminary analysis for environment and output are also shown. For our study, the environment is defined as the current state (your position and department at the time of the interview). I understand that the boundaries between input and environment are blurred and influences can iteratively cycle between the two realms.

The factors in the model that were discussed and coded in our interview are shown in red. Please let me know if you think anything is misidentified/misattributed or if any of the factors shown in the preliminary model were influential but not included in the summary. I am happy to add anything that might be missing.

Questions and points of clarification are shown in italics.

Theoretical Framework: Academic Plan in Sociocultural Context (Lattuca & Stark, 2009), a derivative of the Inputs-Environments-Outputs model

Our preliminary model:



Pseudonym: Luke Harper

Input: Personal Internal Influences

Beliefs: You described how you believe it is your obligation as a faculty member to work toward the ideal embodiment of the engineering profession, which is to collectively solve problems for the benefit of society.

Interests: You expressed personal interest in sustainability, social/ethical/environmental/political/economic implications of engineering, contemporary issues, and social/environmental justice and integrating those topics into your teaching.

Motivation: In developing the fracking intervention, you were intrinsically motivated to integrate ethics and societal impacts (ESI) and engineering fundamentals. The activity also serves as an example for how ethical and social issues can be brought into the engineering classroom without derailing the syllabus. You hope the intervention can inspire other faculty members to develop and implement activities that encourage students to consider broader impacts of engineering.

Role of engineers in society: The idealistic perspective is that engineers solve problems and improve life, but in reality, engineers are responding to the military industrial complex. You are intrinsically motivated to drive toward the ideal and expose students to the impact of engineering and how engineers can work to benefit society.

Professional development: You described how participating in NETI and ASEE catalyzed your engagement in engineering education research (EER) and ESI instruction. These professional development opportunities offered a community of support and ways to develop your personal interests into education and research pursuits. Also, motivated by your own interest in sustainability, you attended the Workshop without financial support from the university or department. In the interview, you described NETI and ASEE as influential on your interest in EER. *Throughout our discussion, I interpreted that your interest in EER and ESI education developed in parallel. Is this correct?* Sort of – my interest and practice of ESI began with my career, developing and teaching [courses] – my interest in EER developed after NETI and this helped gain traction for my ESI interests.

Change in teaching/research interest: You described that you initially felt inadequately prepared to teach social implications and contemporary issues related to engineering in your courses. Finding a community of support, literature on the science behind integrating these topics, and pursuing professional development have helped you move confidently in this direction. One significant influence in your transition into EER and ESI education was tenure. Getting tenure gave you the confidence and freedom to pursue these interests. Although these interests were brewing for some time, tenure offered the autonomy or encouragement to integrate them into your career. Exploring this new area has been daunting but you have found internal and external encouragement to continue.

Role as educator: Expose students to the impact of engineering.

Educational Environment

The environment, at the college and department level, has been supportive of EER and the integration of contemporary issues into engineering. This marks a change since in the past, there was both implicit and explicit discouragement for young faculty to allow teaching and the scholarship of teaching and learning to distract from laboratory research. Within the environment, and discipline more broadly, research is expected to be laboratory based. More recently, colleagues and administrators have become convinced of the value and efficacy of EER and ESI. This movement is new to the institution but there are allies within the department and across campus. Part of this trailblazing effort has been the establishment of the [institution] Engineering Education Research Center. The center has been successful as measured by research money and ASEE participation. The center has also facilitated opportunities for professional development by supporting a workshop series and preparing participants to engage with education research methods and theoretical frameworks.

Within the department, there is a shared ethos that it is the faculty's responsibility to integrate ethics into engineering courses. This is more the result of the faculty who are hired than an explicit mandate from the department. An explicit encouragement from the college and department would benefit this integration.

Do you think the environment at the beginning of your career was a barrier to ESI instruction and research? Sort of – my first teaching assignment was to develop [course], so I was formally encouraged to address ESI; however, this was an oddity for my colleagues and a new/different class for chemical engineering – so somewhat discouraging (informally) and encouraging (formally).

Did promotion and tenure structures prevent you from pursuing these interests or did the interests find traction later on in your career? P&T prevented me from pursuing EER but not necessarily ESI before tenure – I felt liberated to do both in earnest subsequently.

Would you describe your interest and motivation related to ESI as intrinsic or did they develop as a result of the environment? Intrinsic – following the environment solely, I would have stuck to thermodynamics sans impacts thereof.

Educational Outputs
Teaching method: fracking intervention

Course types: upper division technical elective for engineering students, lower division elective open to all majors, fluids required for chemical and biological engineering students

Macroethics: sustainability, environment justice, social justice, contemporary issues, empathy

Assessment: pre and post self-assessment questions for the fracking intervention, follow-up homework questions on related technical concepts in Fluids

C. Copy of initial interview protocol used to select cases for Chapter V

	Only the questions relevant to culture and environment are shown
1.	How would you describe the culture at your institution in regards to the macroethics education of engineering and computing students?
2.	Do you feel supported by your department/school in your teaching of macroethics?
3.	Describe the extent to which you believe other engineering/computing faculty at your institution value macroethics instruction for engineering/computing students?
4.	Is there anything else that you would like to share that I have not asked you about?

D. Copy of recruitment email for academic environment interview for Chapter V

Case A:
Dear Prof. [name],

My name is Maddie Polmear and I am a PhD student at the University of Colorado Boulder. I am part of a National Science Foundation- funded project researching ethics and societal impacts education in engineering. I am conducting interviews with engineering faculty to learn about their perspectives on engineering ethics education. I am hoping to talk to multiple educators in the same department including those who do and do not teach ethics. We have been working with Prof. [name] to study his teaching of ethics and he shared your name with us. I am writing to ask if you would be willing to participate in an interview with me. The interview can be completed over phone or Skype and scheduled at your convenience. You will be compensated with a $50 Amazon card for your time.

Please let me know if you have any questions or would like to discuss this further.

Thank you,
Maddie

Case B:
Dear Prof. [name],

My name is Maddie Polmear and I am a PhD student at the University of Colorado Boulder. I am part of a National Science Foundation-funded project researching ethics and societal impacts education in engineering. I am conducting interviews with engineering faculty to learn about their perspectives on engineering ethics education. I am hoping to talk to multiple educators in the same department including those who do and do not teach ethics. We believe that your department was the site of one of the first courses on engineering ethics in an engineering department. I am contacting you because you served as an associate head of the department with responsibility for undergraduate courses. Would be willing to participate in an interview with me? The interview can be completed over phone or Skype and scheduled at your convenience. You will be compensated with a $50 Amazon card for your time.

Please let me know if you have any questions or would like to discuss this further.

Thank you,
Maddie

E. Copy of institutional culture interview protocol for Chapter V

1.	What courses do you currently teach?
2.	Describe what has influenced your teaching, such as the topics you cover and the methods you use?
2.1	To what extent was your own education as a student influential?
2.2	To what extent was ABET a factor?
2.3	To what extent was your industry experience influential?
2.4	Have you tried to integrate any professional skills into those courses?
3.	Have you ever been involved in ethics and societal impacts instruction in your department?
3.1	If yes, what influenced your efforts to educate engineering students about ethics and societal impacts?
3.2	If yes, did you encounter any challenges in teaching these topics?
3.3	If yes, to what extent did you feel prepared to teach these topics?
3.4	If no, what influenced your decision to not teach these topics in your courses?
4.	Are you aware of how your department teaches ethics and societal impacts?
4.1	If yes, describe the courses in which these topics are taught?
4.2	If yes, do you think these topics are integrated throughout the curriculum?
5.	Do you think graduates coming out of your program have sufficient exposure to ethics and societal impacts of engineering?
6.	How would you describe the culture at your institution in regards to the education of engineering students on ethics and societal impacts?
6.1	The culture within the department?
7.	Do you have anything else you would like to add?

F. Copy of recruitment email for department survey for Chapter V

Dear [faculty name],

We invite you to participate in an ~5-min online survey exploring faculty perspectives on the education of engineering students about ethics and societal impacts. The research is funded by the National Science Foundation (NSF, Award #1540348). We are inviting all faculty members in the [department name] at the [university name] to participate in our study and are seeking a range of opinions. Please complete the survey before March 1, 2019.

You may choose to enter your name into a lottery for a $100 Amazon gift certificate. One survey respondent from your department will be randomly selected to win the gift certificate.

G. Copy of department survey for Chapter V

	Question	Response options	Source
1.	**Permission to Take Part in an Educational Research Study with Human Participants** We invite you to participate in this online survey because of your affiliation with one of the engineering departments included in this NSF-funded study to explore faculty perspectives on the education of engineering and computing students about ethics and societal impacts (ESI). The survey should take about 5 minutes to complete. We are inviting all rostered faculty members in your department and are seeking a range of opinions. You may skip any questions you choose. You may choose whether or not you would like to enter your name into a lottery for a $100 gift certificate to Amazon; one survey respondent from each engineering department will be randomly selected for a gift certificate. The investigators leading this research are: Angela Bielefeldt (University of Colorado), Chris Swan (Tufts University) and Nathan Canney (CYS Structural Engineers). If you have questions, please contact the head of the research team via email at Angela.Bielefeldt@colorado.edu or by phone at 303-492-8433. This research has been reviewed and approved by an Institutional Review Board ("IRB"). You may contact them with questions at (303) 735-3702 or irbadmin@colorado.edu. The results of the research will be disseminated in paper(s) in an aggregated, de-identified format. Please contact Angela.Bielefeldt@colorado.edu if you would like a copy of research findings.	(1) yes (2) no	
2.	Rate the importance of teaching ethics in engineering education.	1 (very unimportant) to 9 (very important)	
3.	Rate the importance of teaching the societal impacts of engineering and technology in engineering education.	1 (very unimportant) to 9 (very important)	
4.	Rate the importance of ethics in engineering education relative to math, science, and engineering science content.	1 (ethics are significantly less important) to 9 (ethics are significantly more important)	
5.	Rate the importance of teaching students about the societal impacts of technology relative to math, science, and engineering science content in engineering education.	1 (ethics are significantly less important) to 9 (ethics are significantly more important)	
6.	Describe the culture experienced by faculty teaching ethics and societal impacts to engineering and computing students: -At your institution -In your college -In your department	1 (very unsupportive) to 5 (very supportive)	
7.	Ethics and societal impacts teaching should be the responsibility of: -Instructors of courses in humanities and social sciences -Instructors of a course in engineering ethics - Instructors of courses in engineering design - Instructors of courses in math, science, or engineering science - All instructors across the undergraduate engineering curriculum	1 (strong disagree) to 5 (strongly agree)	Modified from Romkey, 2015
8.	Rate your agreement with the following statements related to ethics and societal impacts education -With ethics and societal impacts education, students become better engineers.	1 (strong disagree) to 5 (strongly agree)	Modified from Pierrakos et al., 2012

	- Ethics and societal impacts education can be academically rigorous. - It is possible to integrate ethics and societal impacts topics into existing engineering courses without adding to the overall workload of students. - Other faculty in the department/program are supportive of teaching ethics and societal impact topics. - The department head/chair is supportive of teaching ethics and societal impact topics. - The college dean is supportive of teaching ethics and societal impact topics. - Ethics and societal impacts teaching are valued during annual evaluation reviews. - Ethics and societal impacts teaching are valued during promotion and tenure reviews. - Ethics and societal impacts education activities have led to scholarly publications or grants.		
9.	Do you teach engineering and/or computing students about ethics and/or societal impacts in any of your undergraduate/graduate courses?	-Yes, in undergraduate courses -Yes, in graduate courses -I teach undergraduate courses but they do not integrate ethics or societal impacts -I teach graduate courses but they do not integrate ethics or societal impacts -I do not teach courses for engineering or computing students	
10.	In the course you teach most frequently, how much do you emphasize: - the importance of ethical issues in engineering and/or computing - the importance of societal/environmental impacts	1 (little/no emphasis) to 5 (strong emphasis)	Modified from Katz & Knight, 2017
11.	What percentage of the faculty in your department do you believe teach students about ethics and/or societal impacts in one or more of their courses?	0-10 % 10-25 25-50 Over 50 Unsure	Modified from Pierrakos et al., 2012
12. 13.	In your opinion, do **undergraduate** engineering/computing students in your program receive sufficient education on the societal impacts of technology and ethical issues? …**graduate**…	Yes, but too much Yes, a sufficient amount Sufficient ethics, insufficient societal impacts of technology Sufficient societal impacts of technology, insufficient ethics No, not enough Unsure	Bielefeldt et al., 2016
14.	Please share your thoughts about the education of engineering/computing students regarding ethical issues and societal impacts.	Open response	Bielefeldt et al., 2016

H. Nonresponse bias framework for Chapter V

1. Compare characteristics of sample and population

Table 28: Characteristic comparison for population and sample

	Case A		Case B	
	Invited, %	Responded, %	Invited, %	Responded, %
Rank				
Prof	36	33.3	36.9	50
Assoc. prof	23	26.7	10	0
Assist. prof	23	26.7	15	25
Assist. teaching prof	9	13.1	3.8	4.2
Instructor/lecturer	4.5	0	6.8	8.3
Research faculty	0	0	5	0
Prof emeritus	4.5	0	22.6	12.5
Gender				
Male	64	60	90	80
Female	36	40	10	20
Bachelor’s outside of U.S.	4.5	0	48.5	33.3
Bachelor’s year				
2010-2019	4.5	0	3.8	8.3
2000-2009	32	40	19.7	20.8
1990-1999	36	40	19.7	12.5
1980-1989	14	13.3	19.7	25
1970-1979	9	6.7	19.7	20.8
1960-1969	4.5	0	11.4	12.5
1950-1959	0	0	6.1	0

2. Wave analysis

Table 29: Respondents in each wave

Wave	Case A	Case B
1	6	8
2	6	13
3	3	3

Table 30: Wave analysis using Kruskal Wallis Test: statistically significant results for Case A

Survey item	Significance
Importance of ethics in engineering education	0.063
ESI should be the responsibility of: HSS instructors	0.053
ESI should be the responsibility of: math, science, engineering instructors	0.097
With ethics and societal impacts education, students become better engineers.	0.045
The department head/chair is supportive of teaching ethics and societal impact topics.	0.075
The college dean is supportive of teaching ethics and societal impact topics.	0.024

There were not statistically significant differences between responses for participants in the three waves at Case B using the Kruskal Wallis Test.

3. Benchmarking

Table 31: Benchmarking

		Sample, Case A	ChemE faculty*, n=107	Sample, Case B	EE faculty^, n=116
	Full professor	33	36	50	43
	Assoc prof	27	33	0	25
	Assist prof	27	21	25	10
	Female	40	33	21	17
Ugrad	Yes, but too much	0	0	0	5
	Yes, sufficient	44	35	30	32
	Suff ethics, insuff impacts	22	15	18	11
	Suff impacts, insuff ethics	11	19	13	11
	No, not enough	22	31	39	42
Grad	Yes, but too much	0	1	0	5
	Yes, sufficient	25	14	26	35
	Suff ethics, insuff impacts	0	8	14	0
	Suff impacts, insuff ethics	0	10	1	5
	No, not enough	75	66	58	55
*Bielefeldt et al. 2018d					
^Bielefeldt et al. 2018c					

I. Additional survey results for Chapter V

Table 32: Additional survey results, level of agreement (1-5 scale)

Rate your agreement with the following statements related to ethics and societal impacts education.	Case A		Case B		Mann Whitney
	Median	Mean rank	Median	Mean rank	
With ethics and societal impacts education, students become better engineers.	5	22.1	4	17.8	0.248
Ethics and societal impacts education can be academically rigorous.	4	20.87	4	18.61	0.555
It is possible to integrate ethics and societal impacts topics into existing engineering courses without adding to the overall workload of students.	4	21.03	4	18.5	.497
Ethics and societal impacts teaching are valued during annual evaluation reviews	3	19.03	3	18.12	.800
Ethics and societal impacts teaching are valued during promotion and tenure reviews.	3	16.03	3	21.02	.171
Ethics and societal impacts education activities have led to scholarly publications or grants.	3	19.83	3	19.28	.883

J. Copy of recruitment email for non-US Anglo/Western European survey for Chapter VI

Dear [ ]:

We encourage you to participate in a research study that is striving to characterize the ways in which engineering and computing students are taught about the societal impacts and ethical concerns associated with engineering, science, and technology. We are inviting academic staff in engineering and computing disciplines at institutions around the globe to participate in our study. You were selected to represent the faculty at your institution.

The short online survey should take about 5 minutes of your time to complete.

Follow this link to the Survey:

Thank you for contributing your time to this endeavor.

Sincerely,
Angela Bielefeldt, PhD, PE, University of Colorado Boulder
Christopher Swan, ScD, Tufts University
Nathan Canney, PhD, PE

K. Respondent demographics for Chapter VI

Table 33: Respondent demographics

Characteristics	*US respondents % (n=1359)*	*Non US Anglo respondents %* (n=124)	*Western Europe respondents % (n=89)*
Survey solicitation			
Intentionally invited ethics instructor/researcher	26	27	19
Broad solicitation of educators	74	73	81
Indicated teaching no ethics-related topics in any courses	11	12	24
Disciplines taught (could select more than one)*			
Civil	21	13	16
Mechanical	21	18	18
Computer	17	13	22
Electrical	12	21	16
First-year	12	5	2
Environmental	11	2	3
Chemical	10	14	10
Biomedical	9	2	2
Industrial	6	1	11
Humanities/social sciences	6	2	2
General	5	3	2
Aerospace	5	7	3
Materials	5	2	3
Gender			
Male	65	74	76
Female	32	24	21
Prefer not to say	3	2	3

*The following disciplines had less than 5% across each of the 3 groups: agricultural, architectural, biological, eng management, eng physics eng technology, geological, mining, nuclear, petroleum

L. Expanded discussion of methods for Chapter VI

Matching

A matching process was completed to develop comparator samples of US respondents to the non-US Anglo and Western European respondents. The discipline, gender, and survey solicitation were noted for each respondent. For RQ1 (sufficiency perceptions) additional matching criterion was whether or not the individual taught any ethics-related topics in their own courses. For example, there were seven non-US Anglo males in civil engineering who taught ethics topics and completed the survey based on the broad solicitation (not targeting ethics researchers and educators specifically). As a result, seven males in civil engineering at US institutions who taught ethics topics and responded to the co-curricular survey were included in the analysis.

For developing the comparator group of educators who answered the sufficiency question but taught no ethics-related topics in their courses, there was a smaller sample of US respondents on which to match (only 11% of the US reported teaching no topics). In the four cases in which there was no match on all of the criteria, gender was dropped. In previous modeling work, gender proved to be a less significant influence on topic selection than discipline (Bielefeldt et al. forthcoming).

Coding

The responses were analyzed using emergent, thematic coding (Creswell, 2007). Two coders used a random sub-set of 100 responses from the first campaign to develop initial thematic codes. One of those coders analyzed the remaining responses and added emergent themes, generating a codebook with 60 codes. The codebook and 50 responses were shared with another two coders for inter-rater reliability analysis using Fleiss' kappa (Fleiss, 1971). This process was repeated with another set of 50 responses that were theoretically sampled to represent all of the themes present in the codebook.

M. Western European intra-cluster differences for Chapter VI

As noted under the results for RQ2 (topics), there were noteworthy intra-cluster variations for Western Europe. Table 34 reports the percentage of respondents within the Nordic/Germanic and Latin Europe sub-clusters who indicated teaching the ethics-related topics. There were statistically significant differences for eight topics. Since the Nordic/Germanic and Latin Europe respondents were not matched on gender, discipline, or survey solicitation, the differences could be attributed to the environment or be biased by the covariates. For example, 11 respondents in the Nordic/Germanic group were intentionally sampled for their involvement in ethics teaching (33%) compared to six respondents in the Latin Europe group (17%).

Table 34: Comparison of topic frequency with Nordic/Germanic and Latin sub-groups of Western Europe cluster

	Nordic/Germanic (n=33)	Latin Europe (n=35)
Bioethics	6	6
Code of ethics	39*	14
Decisions under uncertainty	52	31
Eng and poverty	6	17
Environmental protection	58	46
Ethical failures/disasters	33*	9
Ethical theories	27*	6
Ethics in design projects	45*	11
Nanotechnology	6	0
Privacy, civil liberties	24	9
Professional practice	48	54
RCR	61*	23
Risk, liabilities	48*	11
Safety	48	29
Social justice	18	6
Societal impacts	73*	37
Sustainability	79*	54
War, peace, military	6	0
Other	15	3
Total	6.94	3.66
		*p<0.05