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Undergraduate Engineering Students' Exposure to, and Valuation of, Ethics Through the Lens of Socialization

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Abstract

Undergraduate education plays a key role in socializing students into engineering. Through this process, students learn the skills and values that shape how they perceive engineering and how they think of themselves in that context. Accrediting agencies, industry employers, and professional societies recognize ethical and societal responsibility as an important part of engineering practice that students are expected to begin developing through their undergraduate education. The present study draws on the framework of socialization to explore students' understanding of the role of ethics and societal impacts (ESI) in engineering. Socialization describes the process of learning the skills and values required for membership in a group. This research paper draws on data from three focus groups that were conducted with a total of 26 undergraduate engineering students at three U.S. universities. The students were enrolled in engineering courses with ESI content, and the focus groups included discussion of the specific course that was being studied by the research team as a potential exemplar of ESI instruction and of students' broader exposure to ESI inside and outside the classroom. In all three courses, the students were seniors and thus could reflect on their undergraduate experience. The focus groups were analyzed deductively using a socialization framework to understand the role of structures, peers, and faculty members in shaping how students think and feel about ESI in engineering. The findings indicated that limited exposure to ESI in the engineering curriculum, the broad inclusion of ethics in non-engineering courses, and the culture of the discipline were influential. These factors in turn affected students' awareness of ethical issues and their understanding of the responsibility of engineers. The findings illuminate the importance of accounting for ESI in the socialization process and point to implications for programs and educators to inculcate the value of ethics in the next generation of engineers.

Introduction

Students learn what it means to be an engineer throughout their undergraduate experience. This process happens formally through the curriculum and informally through the behaviors and attitudes brought on through interactions with faculty members, peers, and various educational settings, e.g., courses and extracurricular activities. It also relates to both the technical and professional competencies that engineering students are expected to develop [1]. Driven by accreditation [2], *The Engineer of 2020* report [3], and industry expectation [4], engineering programs in the United States over the past 20 years have increasingly recognized the importance of ethical and societal responsibility [5]. The need to enculturate ethical awareness and responsibility in engineering education reflects that "engineers hold profoundly important roles as professionals" [6, p. 71].

There has been limited theoretical and empirical research in engineering ethics education [7], with most work in this space focusing on its integration in the curriculum, including the course types, pedagogies, assessment strategies, and learning outcomes [8], [9]. Yet despite the inclusion of ethics and societal impacts (ESI) in the curriculum, various studies have pointed to the difficulty of conveying their importance to students. In a longitudinal study across four institutions, Cech [10] found that students' commitment to public welfare and ethical responsibility declined over time. In their study of second-year engineering students at one

institution, Schiff and colleagues [6] found that participants undervalue and deprioritize ethical issues and professional responsibilities. Other work has also shown that faculty believe engineering students' ESI education is insufficient [11] and that engineering students demonstrate low ethical knowledge and behavior [12]. These findings point to the need to continue uncovering how students understand the role of ethics in engineering. The present study aimed to explore the factors that influence students' conceptualization and valuation of ESI.

Research Questions

This study addressed the following research questions:

1. What factors influence students' understanding of the role of ESI in being an engineer?
2. How are these factors manifested in terms of students' perception of their knowledge and valuation of ESI?

Theoretical Framework

The framework underpinning this study is socialization in undergraduate education [13]. Socialization is the "acquisition and maintenance of memberships in salient groups as well as society at large" [14, p. 294]. The process relies on the transmittance of the knowledge, attitudes, and skills that are characteristic of the group [15]. Socialization spans cognitive (knowledge and skill) and affective (value and attitude) domains to explain how individuals are integrated into a group and develop their professional identity [13]. Through socialization, individuals learn the norms of the group and internalize them in their behavior and identity. However, socialization also recognizes the agency of the individual, which is particularly true as individuals mature into adulthood and have greater control over their group membership [14].

Socialization has provided a lens through which to understand moral personality in engineering education [16], graduate education [17]- [18], and medical education [19]. This study draws on Bragg's [13] framework since it is rooted in undergraduate education. Bragg posits there are three fundamental elements in the socialization process. First, the structures of the education setting, which operate at the program and institutional levels to reflect the goals and values of the setting through curriculum design and teaching approach. Second, faculty members are the "primary socializing agents for the neophyte professional" [13, p. 19]. Educators transmit values and norms formally through their courses and informally through their interactions. Third, the peer group influences socialization as newer members interact with each other and older members and students create a distinct subculture within the educational setting.

Bragg's [13] work provided a formative understanding of socialization in undergraduate education. This framework was selected for the present study to understand how students perceive ESI content, such as ethics knowledge, and develop an understanding of its value in the profession. The integration across the cognitive and affective domains in the framework reflects the interconnection between the two in engineering ethics [20] and morally responsible engineering [21]. Bragg provided a pioneering conceptualization in undergraduate education, but other frameworks have been developed to study socialization in this context. For example, Weidman's [14] conceptual model of undergraduate socialization is based on an input-environment-output framework to account for student background characteristics, academic and social normative contexts in college, and outcomes. Adaptions of the model have also included the influences of professional communities (practitioners and associations) and personal

communities (family, friends, and employers) [22]. The present study used Bragg's framework as an initial exploration of socialization based on the influences that were captured in the focus group protocol. Furthermore, the elements in Bragg's model are more within the locus of influence for engineering programs and educators with a focus on the college experience. Future work could employ a more contemporary and comprehensive model of socialization to understand ESI in engineering education.

Project Context

This study is part of a larger project exploring ESI education. The mixed methods project began with an online survey that was designed to understand educators' practices and perspectives related to ESI (for more information, see [23],[24]). Respondents (n=1448) were asked if they integrate ESI topics in the courses they teach or the co-curricular activities they mentor and were prompted to indicate the characteristics of the setting, pedagogical approaches, and assessment strategies associated with their instruction. At the end of the survey, respondents could provide their contact information if they were willing to participate in a follow-up interview. The interview and selection process has been previously described [25]. From the pool of interviewees (n=37), a subset (n=11) was selected for an in-depth case study analysis of the course or co-curricular activity that was detailed in the interview. The cases were selected as potential exemplars of ESI instruction and were explored through follow-up faculty interviews, student assignments, on-site observations, and student focus groups. This study centers on focus groups from three of the case studies.

Methods

Settings and Participants

Of the case studies included in the larger project, the subset included in the present study was purposefully selected. All three courses that serve as the three case studies were for students in their senior year and thus the students had progressed through most of their undergraduate education, had been socialized in the discipline for the greatest amount of time, and could reflect on the majority of the curriculum and broader academic experience. Additionally, all three of the courses were required, thus eliminating the effect of students' self-selection bias. Lastly, the courses were embedded in different institution types, which enabled the exploration of potential differences across institutional setting. The course characteristics are summarized in Table 1.

Table 1: Course Characteristics

Course	Course 1: Ethics and Professional Issues	Course 2: Ethics and Professional Issues	Course 3: Capstone Design
Engineering Discipline	Biomedical, Computer, Electrical, Mechanical	Civil, Electrical	Environmental
Course type	Required	Required	Required
Institution	Private, religiously affiliated	Private, military affiliation	Public
Course enrollment	34	26	40
Focus group participants (n)	4 male, 3 female	9 male, 5 female	4 male, 1 female

Data Collection
One member of the research team (the first author) visited the three case study sites from November 2017 to February 2018. After observing the ESI instruction in the courses, the researcher conducted focus groups with students. The focus group was advertised at the beginning of class and completed outside of class time. Participation was voluntary and students were compensated with a $10 Amazon giftcard. The giftcard was given to thank the students for their time and was not expected to influence the focus group findings as the research team was not associated with any of the courses.

The focus groups used a semi-structured protocol to understand students' perspectives on the course content and classroom environment and how the course fit with other topics covered in the engineering curriculum and informed their understanding of the role of engineering in addressing ethical issues. The focus groups lasted 25-35 minutes and were audio recorded.

Data Analysis
This research used thematic analysis [26] and deductive coding. The elements of the framework served as anchor points in the analysis to understand the influences on students' understanding of the role of ESI. The influences that Bragg [13] identified (structures of the educational setting, faculty members, and peers) were used as *a priori* codes for RQ1.

RQ2 built on RQ1 to understand the impact of the influences on students' understanding and valuation of ESI. The aim was not to measure students' ethical knowledge or reasoning but to explore their perceptions and meaning making related to ESI and how they factored into students' perspectives on the role of ESI in being an engineer. Given that socialization unites cognitive and affective considerations [13], the analysis began by sorting student perceptions into these two codes.

For both research questions, the first cycle of coding involved examining the transcripts using the *a priori* code. In the second cycle, the transcripts segments within each *a priori* code were revisited to develop more specific categories, which were added to the codebook. In the third cycle, the codebook and segments were reexamined to identity patterns across the data and develop themes. As an example, "structures of the educational setting" was used as an *a priori* code. One category that emerged in the second cycle and was subsumed under this code was "curriculum". The theme that was generated from discussions of curriculum was "the pace and technical focus of the engineering curriculum limited exposure to ESI." The themes are presented in the Findings.

Table 2: Summary of coding scheme for RQ1

***A priori* Code**	**Category**	**Definition**
Structures	Curriculum	The presence or absence of ESI in the formal curriculum
	Program	The goals and values of the program related to ESI
	Institution	The goals and values of the institution related to ESI

	Discipline	The norms and values of the discipline related to ESI
Faculty	Emphasis of teaching	The extent to which individual faculty members include ESI in their courses
	Classroom environment	The extent to which the classroom environment was perceived to be open and comfortable for discussing ESI
Peers	Interactions in the classroom	Discussions and interactions between students

Limitations

One limitation for this study is the small sample size. The findings are not intended to generalize the perceptions and experiences across all the included courses nor all engineering students. The findings are limited to the perspectives of those who chose to participate in the focus group. The number of focus group participants represented 20%, 54%, and 13% of the total course enrollment for Ethics and Professional Issues at the religiously-affiliated, at the military-affiliated, and Capstone Design, respectively. Participation and interest in the subject matter have been connected in qualitative research [27]. Thus, the students who chose to engage in the focus group might have been more interested in ESI as a form of self-selection bias. As a result, the findings may be skewed towards students who are more interested in ESI or place a greater value on the topic relative to their peers who chose not to participate. Another potential limitation is recall bias [28]. Given they were in their final year, students might not have remembered all their ESI-related exposures and experiences, especially tracing back to their first year. Some students mentioned not being able to recall all the topics covered in their introductory courses, so they might not have discussed all the opportunities through which they learned about ESI. The lack of recall, however, suggests that these learning experiences might not have been impactful if they did not retain them after a few years. There are a number of factors that influence socialization, such as family relationships and predispositions, and the focus group protocol and theoretical framework did not capture all potentially salient factors. Future work could address this.

Findings

This section presents the findings by research question. The findings are the thematic synthesis that was generated by extracting patterns from the categories and their associated transcript segments.

RQ1: What factors influence students' understanding of the role of ESI in being an engineer?

Three themes were identified through the multiple cycles of coding to capture the most prevalent influences on students' understanding of the role of ESI in engineering. These themes related to the structure of the engineering curriculum, the exposure to ESI in courses outside of engineering, and the effect of disciplinary culture.

<u>The pace and technical focus of the engineering curriculum limited exposure to ESI</u>

This theme was derived from student responses related to the curriculum category within the educational structures *a priori* code. Multiple students in each of the three courses described that the inclusion of ethical and societal considerations was limited in the densely technical engineering curriculum. A student in the Ethics and Professional Issues course at the military

affiliated institution noted, “this is the only time we’ve really had any mention of ethics.” A student in the Ethics and Professional Issues course at the religiously affiliated institution similarly mentioned, “I was kind of looking forward to hearing a different perspective, all of our engineering classes have been super technical, super mechanically-focused.”

Both the content and the pace of engineering coursework were perceived to provide minimal opportunity to learn about and reflect on ESI. A student in the Ethics and Professional Issues course at the religiously affiliated institution noted, “Our degree is so fast paced, you have to keep going and move onto the next course, but then you forget ‘wait why are you doing this?’” In contrast, this course provided an opportunity to pause and consider the ethical and societal implications of engineering.

A student in Capstone Design also noted the lack of integration of ESI and remarked,

> our ethics have just been sprinkled in there, it’s not a concrete thing we’ve been exposed to. So, for our professionalism class, we only covered ethics in one of the presentations, one of the lectures and it was sort of an overview of the ethics of engineering.

Another student confirmed that ethics were covered in “only two hours” of the professionalism course they had taken the previous semester. Even by their senior year, students in all three focus groups remarked they had limited exposure to ESI in their engineering coursework. This perspective was shared and echoed by participants in each of the courses.

<u>The integration of ESI in non-engineering courses broadened students’ understanding of ethics</u>
This theme was derived from student responses related to the curriculum category within the educational structures *a priori* code. Students were asked to reflect on how the ESI content in the course fit in with other topics during their undergraduate experience. All the students from the religiously affiliated institution described learning about ethics outside of the engineering curriculum through their Bible courses and seminars. Students were required to take a Bible course every semester, which one student described as having a “common theme on the type of person you are.” Students described learning about this broad conceptualization of ethics in Bible courses and this exposure informing their identity as a Christian; however, the content was not connected to engineering and their identity as an engineer. On the other hand, their engineering courses were devoid of ESI content. The students unanimously agreed that Ethics and Professional Issues was the first course that bridged both engineering and ESI and their identities as Christians and engineers.

Students at the military affiliated institution similarly noted the inclusion of ESI in their non-engineering courses offered through ROTC (Reserve Officers’ Training Corps). These required courses included ethics and leadership and overlapped with some of the content in Ethics and Professional Issues but were not generally contextualized in engineering.

This theme was not prevalent in the focus group for Capstone Design in which the students focused on their engineering courses and attributed the inclusion of ESI to the culture of environmental engineering.

The role of disciplinary culture

Structures within the educational setting operate on different levels to inform students' socialization into the program, the university, and the discipline. Within these categories, the most salient factor identified in the data was the influence of disciplinary culture on students' understanding of the role of ESI in engineering, which was mediated through whether it was included in discipline-specific courses. A student in Capstone Design commented "our major specifically focuses on protecting the environment and protecting society and all the people." As a result, courses like Solid Waste were "embedded with ethics." Students in the focus group contrasted this with other disciplines. For example, one student started in mechanical engineering where "a lot of the classes were really just technical and we didn't go over the ethics of whether or not this was responsible." The student described this lack of ethical consideration as his "qualm with the major." Another student in Capstone Design had a similar experience and noted, "I was aerospace for two years and didn't hear ethics once." This perceived disconnection between the material and its application was the primary motivation for switching majors since he "wanted to do something where I wasn't nervous about my designs being used as war machines." These findings suggested structural elements like curriculum design were mechanisms through which students understood and were socialized into their discipline. Reflections on disciplinary culture were most prevalent in the Capstone Design course, but a civil engineering student in Ethics and Professional Issues at the military affiliated institution noted an absence of ESI in the curriculum "apart from the obvious in the environmental classes."

RQ2: How are these factors manifested in terms of students' perception of their knowledge and valuation of ESI?

The findings for RQ2 built on RQ1 to understand how the factors identified above impacted how students learn to adopt the knowledge and values of the engineering profession. Given that socialization spans cognitive and affective domains, the analysis sought to uncover both how students think and feel about ESI.

Awareness of ethical issues

Students in each of the focus groups described that the ESI content in the courses increased their awareness of ethical issues in engineering. One student in Ethics and Professional Issues at the religiously affiliated institution commented, "having the [National Society of Professional Engineers] canons was helpful, I didn't know that existed until this class." The other six students in that focus group also commented that they did not know about professional engineering codes of ethics prior to the course.

Another aspect of students' increased knowledge of ESI was their sensitivity to identifying ethical issues. A student in Ethics and Professional Issues at the religiously affiliated institution commented "it [the course] opened my eyes that there are these situations, just to be more aware of what I'm doing." A student at the military affiliated institution similarly stated that the course "opened my eyes to let me know it's there." A student in Capstone Design described how the class worked through real-life scenarios of engineering practice to identify ethical issues and determine a course of action.

Internalization of the responsibility of engineering

In addition to gaining ESI knowledge and awareness, students described developing an understanding of the impact of engineering and thus their responsibility as engineers. This theme related to the affective aspect of socialization to capture the values and attitudes of the profession. A student from the religiously affiliated institution commented,

> As a biomedical engineer, everything that you do is going to affect people… If you don't have the safety and wellbeing at the forefront of your mind, then you missed the ethical ideal.

A student in Capstone Design also noted the disciplinary effect of this sense of responsibility: "being Envs [environmental engineers], we always think about being ethical and helping society"

This theme suggested that students recognized and internalized the role of ESI in engineering. One approach to facilitate this development in Ethics and Professional Issues at the religiously affiliated institution was a worksheet on identities and values. Students were prompted to reflect on who they were and what they valued and to then connect those ideas to their role as an engineer. This was an impactful experience for one student who noted, "I've never really sat down and thought about what I value." For another student, the emphasis on ESI in the course supported congruence between his personal and profession identity.

> I've been looking for so long like do I really fit in engineering, do I really want to do this. Some of those feelings actually got reconciled through the course and I do kind of see that like I could do well in an engineering setting and do see larger purpose, like macroethically… There are certain ways that I want to conduct myself as an engineer.

By understanding the role of ESI in engineering, he could see himself being an engineer and using it to support the responsibilities of the profession to society.

Discussion

This study explored the factors that influence engineering students' understanding of the role of ESI. Examining the focus group data through the lens of socialization indicated that students' perception of ESI was shaped through both its presence and absence in the curriculum. This finding aligns with the different forms of curriculum through which students learn. The formal curriculum describes the explicitly stated topics and goals, the null curriculum represents the elements that are not included in the classroom, and the hidden curriculum captures the beliefs and values that are implicitly transmitted through the learning environment [29]. Structural elements, like the formal curriculum, codify and communicate the values of the educational setting [18]. The findings in this study indicated that the inclusion of ethics in courses outside of the engineering curriculum, such as Bible seminar and ROTC program, demonstrated the importance of ethics in what it means to be a Christian and officer, respectively. This integration, however, appeared decoupled from engineering and thus what it means to be an engineer. Students across the three focus groups described limited exposure to ESI in their engineering courses, which speaks to the null curriculum. There are many reasons why a topic is not taught,

including the educator's lack of knowledge and deeply held biases about the topic [29] and limited time in the densely packed curriculum [25]. The findings suggested that students are attuned to relative lack of ESI considerations in the densely technical and fast paced engineering curriculum. Through both the formal and null curriculum, students learn what is and is not valued and the hidden curriculum represents this implicit manifestation of beliefs and attitudes. The hidden curriculum has also been described as a socialization process [30] since these beliefs and attitudes define the group into which the students are becoming a part.

Looking across the findings and forms of curriculum provides implications for engineering educators and programs. Students in Ethics and Professional Issues at the religiously affiliated and military affiliated institutions noted this course was their first significant exposure to ESI in their engineering coursework. Saving ESI for the senior year can be problematic since it will appear disconnected from the core of engineering and students' perceptions of engineering and of themselves as engineers have already taken root. Although the inclusion of ESI in non-engineering settings provided a broader exposure to ethics and complement to the narrowly technical engineering curriculum, this approach runs the risk of compartmentalizing ESI outside of engineering. Within engineering ethics education, curricular constraints have been described as a challenge to integration [25]. However, there are approaches to overcome the lack of curricular space while including ESI throughout the degree program. As an example, micro-insertions of ESI context in technical engineering courses can increase students' sensitivity without derailing the syllabus [31], [32]. The approach can be employed across curricular, disciplinary, and institutional settings to infuse ESI.

The findings also indicated differences by institution type and discipline. At both the religiously affiliated and military affiliated institution, ethics were woven into the fabric of the undergraduate experience, although in different contexts. This theme related to disciplinary culture suggested that although the narrowly technical curriculum is perceived to limit exposure to ESI, there are variations within engineering disciplines. This finding aligns with the distinct disciplinary cultures within engineering [33] that are reflected in how disciplines codify ethics in engineering education (e.g., bodies of knowledge) and practice (e.g., professional codes of ethics). Previous work found differences in the extent to which engineering faculty from various disciplines taught ESI topics in their courses [24]. As an example, environmental engineering faculty taught environmental impacts and sustainability more frequently while chemical engineering faculty emphasized safety and industrial engineering faculty taught decisions under uncertainty more commonly.

Faculty members are the primary socializing agents in undergraduate education [13]. By serving as role models, deciding the topics taught in their courses, and communicating the norms and values of engineering, faculty members can exert influence on the ways in which students understand the role of ESI and their responsibility as engineers. As a result, it is important for faculty to be aware of their role in socialization. By including ESI in their courses throughout the degree program, contextualizing the ethical and societal impacts of engineering, and conveying the responsibilities of the profession, faculty communicate that ethics are an integral part of engineering.

Future Work

This exploratory study investigated the factors that influenced students' understanding of the role of ESI in being an engineer and the effect of these factors in students' perception of their knowledge and valuation of ESI. The findings pointed to salient curricular and disciplinary influences and illuminated additional directions of inquiry. Future work could extend the consideration of influential factors, such as family and demographic information, which are included in some socialization theories [14], [22] but were not captured in the focus group protocol and theoretical framework. Future work could also expand the number of case studies to different engineering disciplines, institutional contexts, and course types to understand if the present findings are transferable to other contexts.

Conclusion

This study explored engineering students' understanding of ESI through the lens of socialization. Socialization is the process for learning the values, skills, and attitudes of a group. The undergraduate experience plays a key role in socialization for engineers as it is the only institutionalized training most engineers receive and their first exposure to the culture. As a result, the ways in which ESI are or are not integrated into undergraduate education can exert a significant influence on how students understand their role in what it means to think and feel like an engineer. The findings indicated that students learned about ESI through its limited inclusion in the engineering curriculum, its integration in non-engineering courses, and the culture of the discipline. These influences shaped students' awareness and knowledge of ethical issues and their understanding of the responsibility of engineers. Through the null and hidden curriculum, socialization can sometimes go unnoticed. However, this process is formative in learning and identity formation. Situating ESI in socialization can illuminate the formal and informal elements that influence students' enculturation into the profession and the ways in which undergraduate education can support ESI as a value and norm of engineering.

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