Hidden Curriculum Perspective on the Importance of Ethics and Societal Impacts in Engineering Education

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Abstract

Learning in higher education occurs in many forms; through the official written lessons in the curriculum, the informal conversations and interactions in academic settings, and the tacit messages and attitudes of the organization and culture. The last component, termed the hidden curriculum, pertains to perspectives and processes that are both outside of, and rooted in, the formal curriculum. The hidden curriculum inadvertently conveys to students what is important in the educational community. This paper employs a hidden curriculum perspective to explore the role and value of ethics and societal impacts (termed ESI) in engineering education. As part of a larger study on the ESI education of undergraduate and graduate students, this paper explores ESI through a hidden curriculum lens using an *ex post facto* design and mixed-methods approach. Individuals who teach engineering and computing students participated in a survey where they reported their own ESI education practices and their perceptions of the ESI education. Respondents indicated the course types where they believed undergraduate students learned about ESI in their program. The results indicated settings in which ESI may be invisible or purposefully excluded. For example, despite the clear connection between engineering design and societal considerations, 38% of the respondents reported that ESI was not taught in capstone design in their program. Follow-up interviews were conducted with select survey participants to learn more about their ESI practices and perspectives. The interviews provided insights into the perceived boundary conditions of engineering education and where ESI fits in that paradigm. The interviews were coded inductively and deductively to understand the mechanisms and effects of hidden curriculum in relation to ESI education. This paper aims to create awareness of the influences of hidden curriculum and how making these factors visible can support the thoughtful and effective integration of ESI into the engineering curriculum.

Introduction and Background

Hidden Curriculum

The concept 'hidden curriculum' was first coined by Phillip Jackson in his work "Life in the Classrooms" based on observations in elementary school classrooms [1]. With roots in education and sociology [2], hidden curriculum "serves as one valuable theoretical framework from which to examine the social functions of higher education" [3, pp. 4]. Hafferty and Gaufberg posit there are four categories of curriculum. The formal curriculum is the "stated and intended curriculum… what the school or the teacher says is being taught" [2, pp. 36], it is both intentional and formally identified. The informal curriculum relates to the interactions and relationships in the learning environment. The null curriculum is "what students learn via what is not taught, highlighted or presented" [2, pp.36]; it is the absence that is informative. The hidden curriculum is "neither formally announced nor intended" but relates to the organizational culture of the academic institution [2, pp. 36]. The hidden curriculum serves as a "theoretical construct for exploring the continuities and disconnects of education life", which "highlights the potential gaps or disconnects between what faculty intend to deliver (the formal curriculum) and what learners take away from those formal lessons" [2, pp. 35].

Hidden curriculum is pervasive as it pertains to the "implicit messages… about what is, and what should be, valued within the community" [4, pp.404]. This is inclusive of not only messages that students pick up on in the classroom, it also relates to attitudes and structures at the institutional level. Evaluation criteria, such as faculty promotion and tenure, accreditation, and resource allocation highlight "what is and is not important within the organization" [4, pp. 405].

In higher education, the hidden curriculum framework has been most widely applied to medical education [2-6]. Hafferty argued that attempts to reform medical education have failed because they have been oriented at the formal curriculum. Instead of reforming what students are taught, effective change will result after examining what students learn. It is within this space that hidden curriculum reveals discontinuities and opportunities for improvement since "most of what is learned- in medical school takes place not within the formal course offerings but within medicine's 'hidden curriculum'" [4, pp. 403].

The parallels between medical and engineering education illustrate the applicability of this framework in the engineering context. Both are professions that are bound by codes of ethics [7-8]. Medicine and engineering also rely on formal education to acculturate future professionals [9-10]. This process of "socialization and identity formation" is significantly impacted by "the cultures and related subcultures" that exist below the radar of the formal curriculum [2, pp. 35]. In both engineering and medicine, there has been momentum over the past several decades to reform education. Technological changes and growing stakes have put pressure on medical and engineering programs to evaluate their education to better address society's needs. Physicians, medical educators, and researchers have turned to the hidden curriculum to examine how to improve medical education by illuminating both the positive and negative undercurrents. This paper attempts to take a similar approach with an eye to ethics and societal impacts (ESI) education in engineering.

The hidden curriculum framework has recently been applied in engineering using mixed-methods approaches [11-13]. Preliminary results indicate that negative impacts of hidden curriculum may affect engineering students' self-efficacy, which is valuable for overcoming challenges and taking control in their education, and self-advocacy, which can impair students' empowerment to work against the adverse affects of hidden curriculum. As a result, "interventions developed around HC (hidden curriculum) should equip engineering faculty and students to first recognize HC, analyze the potential internal and external influences, and motivate them to identify appropriate self-advocacy approaches" [11, pp. 9].

The hidden curriculum mechanisms identified by Villanueva and colleagues are especially relevant to the study of ESI. Hidden curriculum can operate through self-efficacy and emotion, and Vanasupa and colleagues [14] posit that mastery and the affective domain are important components in moral and ethical development. Although emotion is often ignored in the classroom since engineering is touted as a rational pursuit, emotion is important in engineering decisions related to morally responsible design [15] and moral acceptability of risk [16].

ESI Education

The adoption of Engineering Criteria 2000 (EC2000) in 1996 by the Accreditation Board of Engineering and Technology (ABET) Board of Directors aimed to shift "the basis for accreditation from inputs, such as what is taught, to output- what is learned" [17, pp. 1] to more accurately evaluate engineering education. The criteria maintained the emphasis on technical knowledge that was part of earlier accreditation but added for the first time "ethical and contextual considerations in engineering" [17, pp. 1]. As a result, ESI has been part of the formal curriculum in engineering since at least EC2000 with the inclusion of "an understanding of professional and ethical responsibility" (criterion 3, outcome f) and "impact of engineering solutions in a global and societal context" (criterion 3, outcome h) [18]. Comparing 1994 and 2004 engineering graduates on self-reports of ability on all outcomes, Lattuca, Terenzini, and Volkwein [17] found that the later cohort indicated the greatest increase in an understanding of societal and global issues and an awareness of ethics and professionalism. These results suggest the positive impact of including ESI in the formal curriculum, but do not capture the ESI education that exists within the hidden curriculum. For the 2019-2020 accreditation cycle, engineering programs have to demonstrate for 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" [18]. The revised language suggests higher levels of Bloom taxonomy [19]. The criterion also implies the connection between microethics, the professional responsibilities of individual engineers, and macroethics, the responsibilities of the profession to consider the impacts of technology and engineering on society [20]. In this research, ESI is used to encapsulate both microethics and macroethics.

Research Questions

This research was conceptualized as an exploratory study of hidden curriculum, driven by two research questions:

1. In which course types is ESI identified as part of the formal curriculum?
2. What are faculty members' perceptions of the mechanisms and impacts of the hidden curriculum in engineering education related to ESI?

Methods

This research employed an *ex post facto* design [21-22]. The data presented in this paper were collected as part of a larger study on macroethics education of engineering and computing students in curricular and co-curricular settings. The larger study was not designed to explore hidden curriculum. However, the larger study examined the settings in which ESI is taught and faculty perspectives on ESI education more broadly. As a result, there was an opportunity to reexamine the data through a hidden curriculum lens and answer the research questions posed in this paper. Engineering ethics education generally focuses on the formal curriculum so the hidden curriculum provided a novel perspective.

Data Collection

The larger study employed a mixed-method design to collect faculty perspectives on the ESI education of engineering and computing students. Two online surveys were developed and refined through pilot testing and interviews [23]. Since educators involved in the pilot testing associated with the survey development associated the term 'ethics' with microethical issues and were unfamiliar with the concept of macroethics, we used the idea of 'ethics and social impacts'

(ESI) of engineering and technology to capture both domains. One instrument, termed the curricular survey, was distributed to recipients of National Science Foundation (NSF) grants, individuals who published engineering ethics-related research, and members of four divisions of the American Society for Engineering Education (ASEE): Educational Research and Methods, Engineering Ethics, Community Engagement, and Liberal Education/Engineering and Society. The second instrument, termed the co-curricular survey, was disseminated to mentors and advisors of co-curricular activities such as service organizations (e.g., Engineers Without Borders [EWB]), professional societies (e.g., American Institute of Chemical Engineers [AIChE]), design competitions (e.g., Human Powered Vehicle), and research programs (e.g., Research Experience for Undergraduates [REU] sites). More detail on the survey development and dissemination has been published [23-24]. The surveys included the same Likert-type questions, open-response items, and demographic questions but in a different order. The curricular survey started with questions related to ESI in courses and the co-curricular survey began with questions on ESI in informal learning environments. The surveys included questions on ESI-related topics, teaching methods, assessment strategies, and perceptions of sufficiency. Respondents were asked to indicate the level of satisfaction with undergraduate students' exposure to ethics and societal impacts in their programs. Following that question, respondents were asked, "where do you think undergraduate students in your program learn about the societal impacts of technology and/or ethical issues?" This question serves as the quantitative basis for the current paper.

At the end of the survey, respondents were asked to provide their email if they were willing to be contacted for a follow-up interview. More detail on the selection and interview process has been published [25]. The interviews were designed to gain additional insights into the settings in which the participants teach ESI (the interview protocol is included in Appendix A) and 37 were completed. Follow-up interviews were completed with a sub-set of 11 faculty members as part of their involvement in the larger study to examine their courses and co-curricular activities in more detail (the interview protocol is included in Appendix B). These 11 in-depth [26], semi-structured [27] follow-up interviews were conducted in-person or over Skype and lasted 30-70 minutes. The interviews were audio recorded and transcribed verbatim. The participants were assigned a pseudonym using a random name generator to protect their confidentiality [28]. The second set of interviews was designed to better understand the personal and environmental factors that influenced the respondents' teaching of ESI and serves as the qualitative basis for this study. Although not designed to explore hidden curriculum, the interviews illuminated some of its mechanisms and effects related to ESI education.

Participants

The surveys were open February to May 2016 and collected a total of 1448 responses. The respondents represented all engineering disciplines and included 375 institutions in the United States. There were 1311 responses to the question regarding the settings in which undergraduate students learned about ESI.

Of the 11 faculty members interviewed for a second time, nine were in engineering departments. To understand culture and hidden curriculum in engineering, only the engineering faculty are included in the present study and they all discussed impacts and mechanisms related to hidden curriculum. Interviews with the two non-engineers were excluded from the analysis and one interview with an engineering educator was a more casual conversation that was not recorded and thus was excluded. As a result, eights educators from the second round were included. An additional two participants from the first round are included in the analysis since the interviews covered a broad range of topics including mechanisms and impacts of hidden curriculum. This sub-set of 10 educators included three women, different ranks (four assistant professors, four professors, one associate professor, and one instructor), and various disciplines (four civil/environmental, two mechanical, one chemical, one electrical, one general engineering, and one engineering education). The sample represents 10 institutions including six public, three religiously affiliated, and one private secular.

Data Analysis
For RQ1, descriptive statistics (frequencies) are provided to shed light on educators' understanding of where ESI is and is not taught to undergraduate engineering students in their programs.

This research aimed to understand how hidden curriculum is operating in engineering education in relation to ESI. Analysis of the interview data combined inductive (codes developed *a priori* and looked for in data) and deductive (codes emerged from the data) coding [22, 29]. The data set (10 interview transcripts) was initially reviewed by the first author and reduced to thematic segments. The segments were first coded inductively based on the hidden curriculum literature. This process was designed to understand if the mechanisms and effects of hidden curriculum reported in studies in medical education and preliminary research in engineering education were present in the experiences of engineering educators included in our sample. The transcripts and segments were then analyzed deductively to allow new codes to emerge in the data. Throughout this process, the deductive codes were added to a codebook that also contained the inductive codes. After the deductive analysis, the author revisited all of the transcript segments with the complete codebook to ensure the codes were applied appropriately and consistently.

To increase the reliability of the qualitative analysis, we used multiple coding [30]. This process includes multiple researchers to cross check the interpretation and application of codes. The first author emailed the second author a random sub-set of interview segments and the complete codebook. We used a negotiated approach in which the first and second authors discussed the codes and transcript segments until consensus was reached [31].

Results and Discussion

The quantitative results from the survey are presented under Research Question 1 and the qualitative findings from the interviews are discussed under Research Question 2.

RQ1: Course Types
The percentage of survey respondents who indicated each course type as a site for societal impacts of technology and/or ethical issues education in their undergraduate program is shown in Table 1. Respondents could select more than one course type and the 122 respondents who marked "unsure" are not included in the analysis.

Table 1: Course types where educators believe engineering/computing students learn about societal impacts of technology and/or ethics

Course Type	n	% (n=1189)
Senior capstone	741	62
First-year introductory	531	45
Sophomore or junior level engineering sci and/or engineering	447	38
Design-focused in sophomore, junior, senior year	390	33
Humanities and/or social science	385	32
Professional issues	324	27
Co-curricular engineering prof society (e.g., AIChE)	297	25
Co-curricular engineering service society (e.g., EWB)	295	25
First-year design-focused	241	20
Full course on engineering ethics	212	18
Other	121	10

The most commonly selected course types for ESI education were (in order of decreasing preference) senior capstone design, first-year introductory, and sophomore or junior level engineering science and/or engineering. These courses are standard in undergraduate engineering programs and thus afford the opportunity to connect ESI with the core curriculum. However, the results suggest that the majority of educators believe that ESI is not covered in engineering science and design courses (except for senior capstone). Although senior capstone was the highest selected course, 38% of the respondents still indicated that students in their program do not learn about ethics and/or the societal impacts of technology in this setting. Accreditation mandates "a culminating major engineering design experience" (criterion 5 d) and requires that students develop "an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors" (criterion 3, outcome 2) [18]. As such, it is surprising that over one third of the respondents did not select senior capstone. However, this result could also be attributed to respondents' limited understanding of courses that they do not teach or difficulty parsing societal impacts from ethics instruction.

Less than a 30% of the respondents indicated professional issues, first-year design-focused, or full ethics courses as settings in which students learned about ESI. This result could indicate that these types of courses are not required in the undergraduate engineering programs. Without a dedicated opportunity in the formal curriculum, it is incumbent on engineering faculty to integrate these topics into their courses [20]. This finding raises questions regarding ESI in the null curriculum, which "refers to what students do not have the opportunity to learn" [32, pp. 88). Without the opportunity to learn about ESI in the context of the technical core of the curriculum, students may see it as divorced. The absence of interactions and discussions around the social and ethical implications of engineering may send the message to students that they are not responsible for considering or questioning these issues. To develop their ethical awareness, reasoning, and behavior [33], students need sustained and repeated exposure to ESI in the formal curriculum and messages regarding its value and relevance in the hidden curriculum. Ethics across-the-curriculum, the incorporation of ethics into multiple core courses, has been advocated as one strategy to foster students' ethical development [34-35] since it contextualizes the material and conveys the interconnection of ESI and engineering.

In regards to co-curricular settings, one fourth of the respondents selected engineering professional society and engineering service society. Co-curricular engagement affords the opportunity to develop professional skills, gain exposure to practical applications in engineering, and increase retention for underrepresented students [36]. With a packed curriculum and seemingly limited opportunities for non-technical content, co-curricular activities can also supplement students' exposure to ESI in the formal curriculum. However, the results indicate that professional and service societies were not commonly selected sites for ESI instruction. In the context of engineering service organizations such as Engineers Without Borders, Engineering World Health, or Bridges to Prosperity, considerations of ethical responsibility and the impacts of engineering seem inherent to work related to infrastructure and public health in developing communities. If the explicit instruction or implicit culture in these organizations does not emphasize ESI, students may learn through the hidden curriculum that these considerations are not important.

RQ2: Interviews
The interviews provided insights into faculty members' experience with hidden curriculum and how its impacts are manifested in engineering education relative to ESI. The interviews with engineering educators were analyzed using inductive and deductive thematic coding. Table 2 displays the codes, definitions, sources, and examples for the inductive codes. The codes were applied to negative and positive effects of hidden curriculum so examples of both are presented.

Table 2: Inductive codes

Code	Definition	Source	(+) Example	(-) Example
Verbal and nonverbal communication	Words, actions, and gestures used by engineering educators to convey values and attitudes related to ESI	[6]	"We try to reinforce with our language over and over again that … everything that we're going to do and talk about is important part of a becoming a professional."	"Language implies that it's something to be gotten out of the way… And typically that language is only reserved for the non-engineering classes…"
Faculty Promotion and Tenure	Processes at the institutional level regarding faculty promotion and tenure	[4]	"And I feel like the tenure at this institution enabled me or gave me the confidence that I needed to explore a new area."	"I'm up for tenure right now… I need a proposal, I need a paper, [as an EWB advisor] I'm wasting, I'm not wasting, but like all my time could be committed to that."
Cultural attitudes	Values and ways of thinking that are dominant in the engineering education community	[6]	"I think in the four years I've been here it's improving and we've gained some traction and a little more respect as an engineering course."	"I actually have run into a couple of times faculty will say what I'm teaching isn't real engineering because we talk about touchy feely things."

Code	Definition	Source	(+) Example	(-) Example
Professional socialization	Process of learning attitudes and skills for future use in a professional role	[2, 5, 6]	"These are topics [ESI] that if you don't understand the point of why we're talking about these things, then you're not going to be a prepared profession."	"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."

Verbal and Nonverbal Communication

In the classroom, both the planned content and the way in which it is organically presented are impactful. It is between these lines, "the space between the official and unofficial… the intended and the perceived" [2, pp. 35] that hidden curriculum exists. This influence can be manifested in the verbal and nonverbal communication; not just the lecture or material but the way it is presented and the way that educators carry themselves in relation to it. Gofton and Regehr expressed this implicit power of faculty because "we are teaching far more than we know. Every word we speak, every action we perform, every time we choose not to speak or act, every smile, every curse, every sign, is a lesson in the hidden curriculum" [6, pp. 21]. This theme was inductively coded in the interviews. An interviewee who teaches an ESI-focused course in mechanical engineering acknowledged, "as a teacher I think that the language we use to describe and introduce and set up things is very important to students." In observing student advising in the program,

> I noticed years and years go, many of my colleagues saying things like 'oh you better take your technical writing class next semester and go ahead and get that out of the way.' Which always really bothered me because that language implies that it's something to be gotten out of the way as opposed to something to enjoy taking and learn something from. And typically that language is only reserved for the non-engineering classes, right?

Non-engineering classes, like writing or ethics, are validated through their inclusion in the formal curriculum but can be marginalized in the hidden curriculum. By becoming aware of the mechanisms through which hidden curriculum is operating, educators can work to mitigate the negative effect. In response to this use of dismissive language, the interviewee "made a big push for... my colleagues and advisors and so forth to stop doing that." His experience showed it was important to reframe because "the language we use can steer student attitudes toward valuing or not valuing." He also connected this to the way he teaches ESI in a junior-level required design course. After students complete their design projects, he and his co-instructor dedicate the last section of class to ESI and he is very cognizant of the importance of presenting the material as not a way to fill time.

> We certainly don't want, to at all costs, say something like 'OK we got a week left we got something'… We treat it as if this is part of the class. It's important. It's just another thing else we've done.

This example provides a positive counterpoint for how ESI can be framed to effectively convey its significance in engineering. If educators present ESI as a valued consideration in engineering alongside technical content, students may be more accepting of the importance and interconnection.

Faculty Promotion and Tenure

Hidden curriculum operates in evaluation of ESI instructors including "issues of faculty promotion and tenure" because evaluation structures and metrics "are vehicles for conveying what is and is not important within the organization" [4, pp. 405]. While formal curriculum is a function of the explicit goals and values of the environment, hidden curriculum operates in the implicit values of the culture within it.

An engineering educator who is the faculty advisor for the EWB student chapter at a public, doctoral, highest research activity institution described the influence that promotion and tenure structures exerted on his co-curricular involvement. The interviewee expressed a strain between his commitment to teaching students about ESI through community engagement and the expectations of being tenure track faculty.

> So basically the whole time I've been on tenure track, I've been the faculty adviser and I've traveled four times with the group. But at the same time I can also see like OK once I get tenure and there's less pressure on myself to be like, OK I need a proposal, I need a paper, I'm wasting, I'm not wasting, but like all my time could be committed to that.

Another interviewee who developed and teaches sustainability electives for engineering students described that tenure was the catalyst for a career pivot. He described that tenure emboldened him to move from traditional lab-based research and teaching of core content in chemical engineering to doing engineering education research and teaching the social, environmental, and economic effects of engineering.

> And I feel like the tenure at this institution enabled me or gave me the confidence that I needed to explore a new area which is still under appreciated by some engineering faculty colleagues of mine.

The hidden curriculum implications in his statement are two-fold; the impact of promotion and tenure on teaching interests and decisions and the lack of value that engineering faculty place on his new area of scholarship. He explained that the timing of his academic shift was not unique because the engineering culture includes implicit understandings of what is important and those values are manifested in more formal structures.

> It's both a perceived and I think very real discouragement that young engineering faculty receive from… traditional administrators that engineering research is in a laboratory and is traditional in the sense that it involves scientific equipment and established research protocol and again, laboratory based. And there is a kind of a discouragement to not allow this distraction, or it's even viewed as a distraction, engineering education research, as a young faculty member… I was told specifically not to allow, my teaching not to distract from my research nor my interest in the scholarship of teaching and learning to distract from my research.

The interviewee's reflection on his pre- and post-tenure experience illuminate several layers of hidden curriculum. At the institutional level, there can be both implicit messages around the value of scholarship and research and more explicit evaluations that directly affect how faculty members design their teaching and research. These structures steer faculty in certain directions that can lead them away from pursuing ESI instruction and research, which directly impacts students' exposure to these topics.

Cultural Attitudes

Although external forces like ABET criteria [18], bodies of knowledge [37], and codes of ethics [8] promote the importance of ethical responsibility and societal context in the formal curriculum, there may be a cultural attitude within engineering that is misaligned. Including a learning outcome in the formal curriculum does not guarantee buy-in from faculty and these disconnections can become apparent in the hidden curriculum. An engineering educator who teaches an engineering service project course at a public, doctoral, highest research institution described the resistance she encountered in developing and teaching the course.

> I actually have run into a couple of times faculty will say what I'm teaching isn't real engineering because we talk about touchy feely things and because our students read papers on the sociological benefit of international development as well as the technical approach… I think in the four years I've been here it's improving and we've gained some traction and a little more respect… But I know that initially it was much more common to think of it as a non-engineering course taught in engineering.

Within the hidden curriculum, there can be a detachment between the technical and non-technical domains, which marginalizes the courses and topics that fall within the latter or attempt to bridge the two. This aligns with the socio-technical dualism that Cech [38] identified as a pillar of the culture of disengagement in engineering. The cultural attitude amongst some engineering faculty that non-technical equates to non-engineering can affect students' perception of these topics. If students pick up this implicit, or sometimes explicit message, they may lose interest or motivation in the ethical and social issues since they are seen as peripheral to "real" engineering. This can impact their learning since motivation, interest, understanding of the broader context, and ethical development are linked [14]. The interviewee went on to explain,

> Occasionally students would apply for a technical elective credit for this and I would have to document what they, what their technical production was in the course and I would have faculty come back to me saying, 'you do that?' Well, yeah engineering is engineering but you need to think about who you're doing it for and why you're doing it to do it right. And yeah there's, yeah there's still pockets of resistance.

This experience reflects that some sub-cultures within engineering are still dismissive of the social applications and ethical considerations of engineering. Another interviewee described the deprecating attitude he encountered toward his education research related to ESI.

> I think there's an under appreciation for it that I think I even bought into initially that 'oh you do education research that seems easy and boy that's a lot safer than the laboratory research I do.' We even have a joke about the dangers of laboratory research is that a student blows himself up whereas with engineering education research, the dangers are paper cuts handing out surveys and I think that's the kind of the impression that many engineering faculty have.

The interviewee's interest in, and pursuit of, education research developed in parallel with his ESI instruction. However, he experienced some pushback from other faculty related to this area of scholarship and research.

Professional Socialization

Professional socialization is "an essential process of learning skills, attitudes and behaviors necessary to fulfill professional roles" [39, pp. 12]. For both academic and social preparation for the engineering profession, formal education is an important driver of socialization. Due to its role in imparting values and messages to students, "hidden curriculum plays a central role in the development of professionalism" [6, pp. 20]. The engineering educator who teaches ESI in a required junior design course explained how he was intentional in his language related to ESI since the content is important for students' professional socialization.

> Throughout the entire semester … we try to reinforce with our language over and over again that what we're trying to do in this class is model a professional environment… and everything that we're going to do and talk about is [an] important part of becoming a professional. … these are topics that if you don't understand the point of why we're talking about these things, then you're not going to be a prepared profession.

ESI is covered through case studies and discussions at the end of the semester and the consideration of ethical and social issues is treated as part of students' professional preparation like any other topic in the course. Another interviewee, who teaches capstone design in environmental engineering, described this opportunity for a positive impact of professional development and her role in it.

> Part of what I think my role is in senior design is to help students transition from being students to being professionals. So toward that end I like to bring in a lot of not just professional level project experience that they would have like open-ended problems and clients that ask for one thing and want another.

Although the formal curriculum in capstone design was changed so that professional issues and ethics were moved to a separate course, the instructor explained the value of implicitly integrating these topics to support students' professional development and preparation. "The habits and dispositions of thought and conduct, the things we come to care about, are shaped by our socialization, including our professional socialization" [5, pp. 206] so educators should be aware of the influence of hidden curriculum to ensure the values and attitudes being transmitted to students support their ethical development.

Codes related to hidden curriculum also emerged in the data analysis and are displayed in Table 3.

Table 3: Deductive codes

Code	Definition	(+) Example	(-) Example
Placement and structure in formal curriculum	Decisions regarding where in the curriculum ESI is taught	"We wanted our ethics requirements really to be met by distributing it throughout the curriculum."	"Our students all take a course from the philosophy department on science and values… but I think it's disconnected from the real world."
Content and presentation of ESI	Decisions regarding how ESI is taught	"We want to start bringing those engineering ethics conversations into their immediate experience… into their day-to-day experience both as a student and apply immediately upon graduation."	"We do a disservice when we do these big case studies… it's one thing to talk about engineering ethics on this big stage scale but it's another on an individual scale."

Placement and Structure in Formal Curriculum

The location of ESI in the formal curriculum can send certain messages in the hidden curriculum. ABET mandates that students in accredited programs demonstrate the attainment of ESI outcomes [18], but departments and programs have significant autonomy over how those outcomes are achieved. Decisions regarding how ESI is taught are the confluence of a range of factors such as curricular space, faculty expertise and teaching load, and university general education requirements. These decisions have implications beyond the course setting in which students receive formal exposure to these topics. An interviewee described his perspective on the importance of placement in the curriculum.

> I 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… there might be an engineering ethics course because it seemed like it was a standalone thing that you could ignore.

Divorcing ethics from core courses, including design, in the curriculum may imply that ethics and engineering are divorced in practice. The interviewee concluded, "ethics needs to be integrated throughout the curriculum." If ESI is not distributed throughout the coursework and integrated with core content, students may perceive it as tangential to engineering, which can impact their ability to recognize and resolve ESI issues in their careers. Conversely, including ESI across the curriculum sends the message that these considerations are inherent in engineering and invaluable skills for their future profession.

Another interviewee who teaches Introduction to Engineering noted that the course includes ethics and supplements a full course on ethics that all students on campus are required to take.

> Our students all take a course from the philosophy department on science and values, which sort of understands sort of the theoretical aspects of ethical decision making and methods of thinking about ethical situations. And it feels like at the end of the day the students all say they learn a lot about ethics. But I think it's disconnected from the real world.

Outsourcing the ESI instruction to a humanities or social science department is one common way to cover the content, and usually fulfill a university core requirement, while not detracting from the already crowed engineering coursework [34]. However, consideration should be given to the message that this placement sends to faculty members and students and to students' ability to transfer these outcomes in an engineering context (e.g., "the real world").

Content and Presentation of ESI

The most common method for teaching ESI is case studies [40-41]. Historical and contemporary stories of engineering ethics disasters and failures can be effective for engaging students and demonstrating the high stakes of their future profession. However, this approach may have limitations that lurk in the hidden curriculum. If students are primarily exposed to ESI in the form of large-scale case studies (such as the Challenger shuttle explosion or Ford Pinto), they may have a narrow understanding of the ways in which ESI issues emerge in engineering practice. The majority of engineering graduates will not have the responsibility to decide the fate of a space shuttle and students may have difficulty relating to the issues presented in the case studies. Perlman and Varma [42] describe this as an issue of "professional distance" in which scale (size of the case), currency (temporal distance), locale (physical distance), and individualism (individual engineer painted as hero or not). Students may perceive that ESI is constrained to these large-scale case studies and thus may be unintentionally blind to the ESI issues that they are more likely to encounter in their day-to-day careers. This approach may also imply that only seasoned engineers and managers who are responsible for big projects are susceptible to ESI dilemmas and mistakes. An interviewee who teaches a professional issues seminar commented on the use of these classic case studies to teach ESI.

> I think that very often, so for example, you know, we often talk about the grand, big, the Tacoma Bridge, the Challenger Space Shuttle, Hyatt Regency Hotel, all of these sort of grand failures where lots of people died. And much less frequently do we talk about the small day-to-day decisions, which cumulatively impact, that are sort of small but when integrated, are a much bigger loss than the losses associated with these very acute events. And I don't want to take away from these large, very acute events where many people died or a lot of money was lost, but the losses associated with the small day-to-day choices probably add up to a much larger value.

Focusing on these cases can divert attention from the ESI issues that engineers more frequently face in their work and these issues can have significant impacts on the individual and society at large. Another interviewee described the limitations of case studies in the message that they imply to students.

> We do a disservice when we do these big case studies. If we look at something even like, you know, recent things with a few years ago we had the Volkswagen scandal or the General Motors issue a year before that. And it's clear and you can read these cases, those were bad actors, right?

When cases are presented as situations in which the ethical mistake was obvious, students may learn that ESI issues are black and white. This implicit message can desensitize them to the intricacies and nuances of ethical and social issues that they may encounter in their own careers. To address this issues, the interviewee continued to describe the approach to teaching ESI in the introduction to engineering course.

> It's one thing to talk about engineering ethics on this big stage scale but it's another on an individual scale. We want to start bringing those engineering ethics conversations into their

> immediate experience… And so how can they [students] say, 'well we understand engineering ethics but at the same time behave in ways that we'd say, 'well that's not ethical.'

To bridge ethical understanding and behavior, the interviewee emphasized the immediacy of ESI in engineering by focusing on personal ethics rather than traditional case studies.

Implications and Limitations

Hidden curriculum is pervasive in higher education with impacts on what students learn and how they perceive their future profession. Examination of the hidden curriculum in medical education indicated effects such as "loss of idealism, the ritual attainment of professional identity, emotional socialization" [5, pp. 197]. These results also have meaningful implications for ESI education in engineering. Although ethics education can be adversely impacted by hidden curriculum, it can also provide a means to mitigate the negative effects. Ethics education "seems a necessary antidote to the sorts of potential 'disabling effects'… which have implications for moral development" [5, pp. 205].

Hidden curriculum can reflect the values of the institution and have more acute effects on student learning by reflecting the values of educators within it. The first step in mitigating the adverse outcomes of hidden curriculum and highlighting its positive impacts is understanding how it operates. To bridge the gap between the formal and hidden curriculum, educators and administrators must be "aware of the phenomenon, and ensuring that others in the learning environment are aware and open to discussion as well," as this can "often can be a big part of the solution" [2, pp. 37]. This awareness is important because "most engineering educators do not realize that they may currently render invisible SJ [social justice] dimensions that are inherent in the engineering concepts they tech, simply by teaching engineering course as they themselves were taught" [43, pp. 45]. Reflection on the role of macroethical issues, like social justice, in the hidden curriculum can help make them more visible in engineering education and convey their relevance in engineering practice to students. An example of negating a negative hidden curriculum against ESI exposure is to complement formal curriculum with a requirement for students to take advantage of various opportunities for co-curricular engagement that also support ESI education. If engineering service organizations like EWB and professional associations such as Order of the Engineer are offered on campus, ESI can be a stronger part of the culture, which transmits its value to students through the hidden curriculum.

This exploratory research applied a hidden curriculum lens to understand the implicit messaging that is embedded in engineering education related to students' instruction on ESI. One limitation of the quantitative analysis is that the data are self-reported and constrained by the survey respondents' awareness of ESI education in their program. The selected settings are reflective of their familiarity with the curriculum and perception of what counts as ESI instruction. Future work could use document analysis to corroborate these results by exploring the inclusion of ESI in course syllabi, catalog course descriptions, and program curriculum requirements.

One limitation of the qualitative component of the study with a small sample is generalizability. The perspectives expressed in the interviews are not intended to be representative of the engineering education community at large. Instead, the perceptions and experiences discussed in the interviews shed light on the possible mechanisms of hidden curriculum and how they might be impacting teaching and learning related to ESI. Another limitation is that the interview protocols were not designed to explore hidden curriculum. Future research could explore this more explicitly by asking engineering faculty to describe their experience and perceptions related to hidden curriculum.

Conclusions

The next generation of engineers needs to be trained to consider their role in a global context and their ethical responsibility to society. This paper examined ESI education through a hidden curriculum framework to explore to what extent these desired outcomes are reflected in the engineering culture. Interviews with engineering educators revealed that verbal and nonverbal communication can be used to the detriment or benefit of ESI instruction. The ways in which educators present ESI conveys the value that they place on the topic, which in turn, shapes students' attitudes related to it. The effect of hidden curriculum also operates at the institutional level as its values are manifested in promotion and tenure. The scholarship and research that is rewarded in these structures conveys to the faculty what is considered important and legitimate and this messaging is transmitted implicitly or explicitly to students.

Hidden curriculum operates through cultural attitudes as some ESI educators are still fighting against the tide of prioritizing technical content and marginalizing ethical and societal issues. Half of the interviewees described resistance from their colleagues related to their ESI instruction and research and presumably students are also exposed to this devaluation of ESI by some of their professors, which can impact their motivation and learning. Student learning is also impacted by where ESI is located in the curriculum and how it is taught in those settings, with both positive and negative implications.

Education reform usually begins by looking at what is formally taught. Programs often respond to calls for improvement or changes in accreditation standards through "supplementation or addition of new material"; however, "if we truly hope to improve more than just the coursework in our training programs, then change in the culture of our learning environments is required" [6, pp. 24]. Turning an eye to the hidden curriculum can reveal ways in which the culture of an organization affects ESI education, the role that educators play in conveying the importance of ESI, and ways in which educators' instruction and student learning related to ESI can be better supported.

Acknowledgements

This material is based on work supported by the National Science Foundation under Grant Nos. 1540348, 1540341, 1540308, and 1755390. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

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Appendix A: Initial Interview Protocol

1.	Tell me about the exercise/project/class that you teach which you believe is most effective in facilitating ethical development in your students.
2.	What pedagogical approaches do you use in this exercise/project/class and how do you think they work?
3.	What makes you believe that this approach is effective?
4.	What were your motivations and goals in designing this exercise/project/class?
5.	What is your understanding of macroethics and how it is distinguished from microethics in engineering?
6.	What challenges have you encountered in teaching macroethical topics? With respect to students? Other faculty?
7.	Do you perceive students as being interested in the topics that you cover in this exercise/project/class?
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 exercise/project/class 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?
10.	How would you describe the culture at your institution in regards to the macroethics education of engineering and computing students?
11.	Do you feel supported by your department/school in your teaching of macroethics?
12.	Describe the extent to which you believe other engineering/computing faculty at your institution value macroethics instruction for engineering/computing students.
13.	Is there anything else that you would like to share that I have not asked about?

Appendix B: Follow-up Interview Protocol

1.	What do you view is the role in society of engineers and/or computer scientists?
2.	Describe what has influenced your current efforts to educate engineering and computing students about ethical and societal issues.
2.1	To what extent did you feel adequately prepared to teach students about ethical and societal issues?
2.2	Have you engaged in any professional development around these topics? Such as attending workshops or reading literature?
2.3	To what extent is ABET and accreditation a factor?
2.4	To what extent was your own education as a student influential?
2.5	Was time in industry influential?
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?
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?
4.1	Have you ever felt student resistance?
4.2	Do you feel that students have differential interest in certain topics or pedagogies?
4.3	Have you perceived any differences among students – such as among different majors, ranks (first-year vs. seniors vs. graduate students), gender, etc.?
5.	How do you assess the outcomes of your teaching practices around ethics and societal impacts?
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?
6.1	Do you integrate ethical/societal issues to some extent into all of the courses that you teach?
6.2	Are your practices part of ethics across the curriculum?
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?
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?
7.1	In your college?
7.2	At your institution?