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The Undone Ethics of Engineering Ethics

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Introduction

Under the ABET accreditation standards, engineering students who graduate from accredited programs should possess certain practical ethical competencies. Many engineering schools and majors require students to participate in various forms of ethics learning experiences or programs. Yet students feel unequipped, under-exposed, or lacking the knowledge, skills, and vocabulary to make informed and well-justified ethical decisions. Their engineering coursework does not prepare them to feel confident or competent in ethics. Based on our qualitative data utilizing situational analysis of semi-structured interviews, we attribute this lack of competence to "undone ethics" in engineering education. Here, we want to formulate what the ideas around undone ethics might look like, particularly in the context of engineering education and engineering ethics. This paper develops the terminology "undone ethics" through exploring the concept of "undone science," drawn from literatures of science and technology studies (STS). Undone science is defined as research that has been "left unfunded, incomplete, or generally ignored"[1],[2]. In order to map out the connections of undone ethics to undone science, we attempt to create a typology of undone ethics, drawing from empirical, qualitative data through interviews with engineering students at a private research university.

We offer three explanations as to why undone ethics occurs in the engineering education setting despite ABET's attempts to incorporate ethics as a practical competency in engineering students. First, when there is any discussion of ethics, it frames ethics as an exploration of safety through examples of accidents, failures, and disasters. In other words, their training to explore and work out ethical considerations typically does not occur during the design process. Instead, ethics content is presented through post hoc events with clear ethical stances and stabilized conventional frameworks. Thus, while students may be equipped to understand ethics through safety guidelines, they are unable to navigate the grey areas or nuances of engineering ethics that do not take that form. Second, engineering tends to create a boundary separation of the social from the technical, which we refer to as the demarcation problem. The social knowledges and skills in engineering tend to be shunted into non-engineering courses or low-stakes, minimal effort exercises within engineering coursework. As ethics is not viewed as a technical skill, it is not given high importance by engineers, thus left out of engineering lessons. Third, an implicit understanding of engineering ethics is considered to be tacit knowledge. Engineering students are expected to have some understanding of ethics before entering the classroom. Because they are assumed to already, somehow, carry this knowledge, the notion is that ethics does not need to be taught. Thus engineers rarely have formal education on ethical concerns in engineering. Even rarer still is culturally or situationally specific knowledge about ethics. We conclude this paper

by offering suggestions for further research on undone ethics and how educators can apply it in the engineering context.

Undone Ethics and Science and Technology Studies

Science and technology studies (STS) examines how science and technology are active social and political processes by "investigating how scientific knowledge and technological artifacts are constructed [3]." From the field of STS, undone science examines the social production of ignorance in the sciences by studying the "areas of research that are left unfunded, incomplete, or generally ignored but that social movements or civil society organizations often identify as worthy of more research" [1] and "the historicity and artifactuality of knowing and the non-known [4]."

In this definition, there are two significant aspects of undone science. The first focuses on the ignored scientific research due to various misunderstandings relating to prestige and capital losses that the research may create. This research either hasn't occurred or is of little to no importance, thus gaining no traction in the larger field of its research. For example, even though Big tobacco companies fund research on tobacco products, they consciously choose to ignore the results and push tobacco products to the public in order to profit from their products [3], [4]. In the example of breast cancer research, environmental breast cancer research discussed the struggles in demonstrating the credibility of the Silent Spring Institute [5]. The second significant aspect of undone science is the involvement of research that lies outside the institutional parameters of science. Participatory-based research and citizen science are other forms of resistance to ignorance classified as undone science due to the lay inclusion in the research process [6]. While the research of undone science occurs due to ignorance within academia, participatory action research and citizen science rely on the inclusion of lay people for collecting data and developing lay knowledge in the research process.

In understanding the work of undone science, we need to also look at how forms of knowledge are left unaccounted for [7]. In other words, what forms of knowledge are left undone? Here, we turn to take the question seriously, what are the forms of undone ethics within engineering education? Particularly, we are interested in how students engage with ethical topics or situations. For instance, in Cech's exploration of student interest in public welfare, the longitudinal survey data found that engineering students' interest in public welfare concerns significantly declined during their engineering education [8]. We were interested to see if this was similar to our student data. However, this is strongly oppositional to what the students in our interview anticipated, hoping that their higher-level engineering courses would cover ethics more in detail than the introductory courses.

While we know that students are exposed to ethics in forms such as general education, stand-alone engineering ethics courses, ethics modules in engineering courses, and such, in a way, students are also left with an "undoneness" of engineering ethics. Here, we mean that there are instances and circumstances in which authentic, integrative ethics learning opportunities may be left out of the engineering classroom, whether implicitly or explicitly.

Methods

We designed this project to explore engineering students' holistic experiences of learning about ethics during their time in university. What are the different mechanisms (explicit and implicit) that affect students' perceptions of personal moralities, professional responsibilities, and the social impacts of technology? Using qualitative methods, over 30 semi-structured interviews were conducted with engineering students at a private undergraduate university. Students were approached for interviews based on their engineering major via Discord groups.

Discord is a social media application that the video gaming community has primarily utilized. However, during the COVID-19 pandemic, Discord became an online space for students to regroup and form study groups and club/organization spaces away from the physical university campus. On Discord, users can send/receive instant messages, host video, and audio calls, and digitally distribute files. Users can also indicate certain aspects, such as major and class year, to their user profile. Within Discord, users can join servers that function as micro-communities between friends and acquaintances. Users can only join a server after a verification process or an invitation. Due to this extra level of security, Discord cannot be considered a public site. Researchers had access to various university-connected Discord servers where they could reach out to students. Over 30 interviews were conducted in-person, with COVID-19 guidelines, and online via Discord. Interviews, which lasted from 45 minutes to 3 hours, were audio-recorded and transcribed. Once transcribed, transcripts were coded for student responses using a native coding scheme [9].

The interview protocol was formulated to introduce the concept of engineering ethics to the students broadly. While questions were semi-structured, flexibility in questions allowed for open trajectories of student responses. Students were first asked to describe their own understanding of ethics through examples and anecdotes. Then, students developed their own definitions of ethics regarding personal, professional, and social responsibility again, using examples from their lives in and out of the classroom.

Using situational analysis, transcripts were coded to interpret the students' experiences with ethics during their time at the university. Developed in conversation with grounded theory, situational analysis takes "the situation as the unit of analysis which the researchers then map in order to analyze it [10]" [11]. Codes were grouped together to form the typology, laid out in the

following section. The three codes deciphered from the interview transcripts were related to safety, engineering ethics' social/technical debate, which we refer to as the demarcation problem, and tacit knowledge.

As data were collected and interpreted during the COVID-19 pandemic, we must also recognize that the pandemic has created a space for time and reflection about the education process and rethinking how we teach and learn. It provided engineering educators with opportunities to engage students in reflecting on how engineering expertise and creativity can help address socioeconomic and racial inequalities exacerbated by the pandemic [12].

To protect student identities, the only identifying information included with quotes throughout this paper will be year and major, for example, Freshman, Mechanical Engineering. Identifying information such as university names, courses, or departments has been removed and generalized within brackets [ ]. Quotes have been approved for publication by the interviewed students.

Typology

To outline undone ethics, we have developed a typology of undone ethics. The first addresses an emphasis on safety, which we argue is the one clear case of engineering ethics. In instances when engineering professors do acknowledge or discuss ethics in the engineering classroom, these discussions are typically reflections on accidents, disasters, or failures in the engineering realm. In other words, safety locates ethics at the extremes rather than being a fundamental part of "good design." Next, we look at the first example of undone ethics through what we refer to as the demarcation problem. With the demarcation problem, we look at the normative boundaries inscribed to demarcate where formal education in engineering ethics should occur. From our interviews, students indicated uncertainty about where and whom should teach engineering ethics. Is this a role for the social sciences and humanities (the social) or engineering (the technical)? The uncertainty reinforces that without the social aspect of engineering, engineering continues to be a field dominated by a culture of disengagement or lack of consideration for the social aspect alongside the technical. And third, tacit knowledge focuses on the stance that ethics cannot be taught through formal education but through implicit means such as extracurriculars, values, and beliefs. However, students develop this tacit knowledge in understanding engineering ethics both in and out of the classroom.

Safety

Before we dive into two examples of undone ethics, we want to provide an undeniable standard of engineering ethics – safety. Safety as a public and social value goes back to Cicero's Creed "[s]alus populi suprema est lex," or "the health and safety of the people shall be the supreme law [13]." Ever since, safety has been considered paramount for ethical considerations in

engineering, as cited in the codes of ethics for various professional engineering societies [14], [15], [16], [17]. Regardless of language or culture, all engineers can understand the importance of safety, thus an essential aspect of the engineer's education [18]. And within the codes of ethics for various engineering societies, safety is aligned as a central role for the engineer. Discussions of failures, accidents, and disasters were the prime candidates for course discussions on ethics. One of the most common methods of incorporating safety education was through case studies.

Case studies were the most widely used example for teaching ethics in the engineering classroom [19], [20], [21]. However, cases such as the Challenger incident have a clear and explicit connotation to what went wrong in the specific situation. For instance, while we interviewed a variety of majors and class years, many cited the Challenger accident as one of their first forays into engineering ethics and the structures around the accident. Learning about the "systems or processes that workers …may have overlooked...really analyzing the cause and effect of every small action that would then transfer to a bigger failure or issue" (Senior, Electrical Engineering) indicates a right and wrong aspect to the accident. Yet these students recognize that there is a slight chance they will experience exposure to Challenger or Chernobyl level events. They know that the smaller day to day scale decisions and situations are what will become the problems they face. For instance, one student states the importance of OSHA (Occuapational Safety and Health Administration) regulations and the lack of coverage of safety protocols in the classroom:

> *[I]f you turn a blind eye to people violating OSHA, someone falls off a ladder and dies. That's a more practical example. They don't really go over some of that stuff.* -Senior, Aerospace Engineering and Mechanical Engineering

In this case, they view the smaller everyday tasks are not covered in class. Another student describes the minimal class discussion behind ethical considerations in regards to building design:

> *[W]e may have a quick, approximate comment or two like 'Oh, you can't design a building that breaks, you know?' and we all know the reason why we're designing this building so that won't break. That's the extent of what's being said [in class].*
> -Sophomore, Mechanical Engineering

And another student recognizes the importance of safety considerations for design:

> *When we take out the thought of people's safety and you start building for other reasons, or you start leaving things out, or whatever the case may be, you start to have failures and you have disasters.* -Senior, Civil Engineering

Thus, in the design and implementation stages, ethical considerations are not included in the design process but rather in a post hoc fashion, where there are clear ethical stances. These students do not feel prepared for the "gray" areas of engineering ethics, from small mundane examples to discussions about the political role their actions may play. Perhaps this is due to the notion within engineering to remain objective and politically neutral. However, it must be clear that it is impossible to remain completely objective within engineering [20], [21]. This begs us to ask, how then do these students learn ethics and begin to face some of the larger grey areas within engineering?

Though students are geared to learn about engineering accidents and disasters that had direct and consequential outcomes, including loss of life, ethics is never framed as a complex or uncertain matter but rather one in which there is a clear "right" answer. For instance, one of the most asked questions among engineering students is whether one might take up a future position at a company that builds missiles or systems that guide drones. Many students cited that working for such companies is unethical when asked about social responsibility [22]. However, when asked whether they would accept such employment, if in a financial pickle, they did not know what they would do and did not seem to have recourse to a vocabulary with which to frame responses in structural or systematic rather than individual or personal terms. Yet these are the types of situations that engineering students face, and engineering educators need to consider these circumstances. And because of the boundary act that engineering ethics plays, many engineering educators decide not to include these discussions in their courses because they do not see themselves as responsible for this kind of material. However, students still aim to find ways to connect themselves to their professors. Perhaps sharing more about their industry experience and decision-making can help create better critical-thinking engineers.

Demarcating the Value of Ethics

Perhaps the most prominent conversation within the engineering ethics community is precisely where engineering ethics should be housed [21], [23], [24], [25], [26], [27]. At some institutions, engineering ethics is housed in the humanities or liberal arts, typically history, philosophy, or sociology courses [19], while others house it within engineering. Currently, there is no complete consensus on where engineering ethics should be taught according to ABET accreditors due to the "outcome-based" nature of ABET accreditation policies [19]. In other words, ABET evaluators will check the box of ethics learning insofar as engineering programs can identify components related to ethics in their existing curriculum and articulate the ethical relevance, sometimes weak, of these components.

While this flexibility recognizes different institutional structures and curricular processes, it also feeds into what we refer to as the demarcation problem. The demarcation problem refers to a form of undone ethics in which there is uncertainty about the location of engineering ethics

within the engineering curriculum. For some, since ethics is related to philosophy, engineering ethics should be housed in the humanities. For others, engineering requires consideration of society and location, so engineering ethics should be housed in engineering. Does it belong in the engineering classroom? Does it belong to the humanities or liberal arts? This confusion of pointing and feeding back to each other comes across in our student interviews.

At the university studied, the engineering ethics course is housed in a humanities-related series of three engineering professional development courses. Students acknowledged confusion when pinpointing the exact location of ethics within their own engineering education. Particularly with first- and second-year students, students were unsure if any instruction on engineering ethics had even occurred during their college education.

> *[T]he whole idea of consistency, they need to get consistency between courses and departments.* -Freshman, Undeclared Engineering

> *I don't think there's necessarily anything that specifically addresses ethics that's required of me in my degree.* -Sophomore, Chemical Engineering

Some students cited their introduction to engineering ethics in philosophy or logic courses; others cited sociology courses, while others talked about ethics in their major engineering courses. One student mentioned that even though these discussions occurred during class, their professor only talked about such topics while waiting for students or during class breaks. Yet on the other side, first- and second-year students expected some form of ethics education in the upper-level courses:

> *Well, they probably wait to discuss the ethical implications of our teachings until later on in our education. If it ever comes up...[engineering ethics] isn't going to bring the school as much prestige in the long run as teaching kids how to do a bunch of stuff.*
> -Sophomore, Electrical Engineering

This quote regarding prestige of the school brings another essential aspect of the demarcation problem. Many engineering education scholars have highlighted engineering's tendency to create and enact hierarchies of knowledge [28], [29]. "Teaching how to do a bunch of stuff," referring to the technical, or nuts and bolts [29], becomes far more prestigious than the social skills. Yet the social skills become vital for becoming a hirable engineer [27]. The hierarchy of knowledge becomes a secondary factor where engineering ethics becomes important. Faulkner's ethnography of programmers found that engineering profession identities pervade a strong dualism that favors the technical while diminishing the social [28], [29].

One of the more jarring aspects of the above quote, from the electrical engineering student, comes from the student's uncertainty about whether ethics come about, which they doubt in some sense. The perception that the university's focus is to produce technically-trained engineers, not necessarily socially-minded engineers, comes through in the quote. Similarly, another student notes the aspect of their ethics education has come primarily from the humanities, not engineering:

> *I know that I'm supposed to have some ethics lessons during one of my [engineering] classes later in the future this semester, but we haven't gotten there yet. But I haven't really learned about it, not as an engineering student, as like a [humanities] student we talk about ethics a bit more.* -Senior, Mechanical Engineering

Students believe professors play a part in the lack of ethics in engineering. The valuable conversations imperative to building and fostering an ethical mindset as an engineer are lacking in discussion with their engineering professors. They spoke on how professors try to only focus on one thing at a time rather than try to tie in other variables such as the social in engineering:

> *Professors are very, not necessarily monotonous, but they definitely like single focus.* -Sophomore, Aerospace Engineering

Along with the previous quote, another student recognizes the similar manner in which engineers also follow the one-track mind, which professors have showcased:

> *[W]hat I've found with structural engineers, and even some professors is that [they] tend to be very one-track. And oftentimes, there's not a lot of thought, outside of what they're either directly focused on or anywhere outside of their comfort zone … Like, it's not single track at all. It's thinking about different platforms, and it's a very multifaceted approach to the way you look at things.* -Senior, Civil Engineering

With the inability to pinpoint the exact location of where engineering ethics should be housed, the demarcation problem lends itself to describing one form of undone ethics in engineering education. It becomes apparent that the inattention to ethics in their engineering courses indicates that among engineers, ethics may not be viewed of high importance. As it blurs and connects the sociotechnical sphere of engineering and philosophy, the demarcation problem is another area of engineering education research that compromises and contains the impact of interdisciplinary work.

Tacit Knowledge

The second category under which we classify undone ethics is tacit knowledge. Philosopher Michael Polanyi develops tacit knowledge as an understanding that describes the ability to define or understand something without articulation or awareness by dwelling in situations [30]. Thus, the tacit dimension of knowledge is indispensable for any act of knowing as it underlies all empirically based observation [30]. Due to this inability to clearly articulate tacit knowledge, it remains a form of knowledge difficult to formalize, "nearly impossible to transfer to another person except through methods such as observations, imitation, socialization, the use of metaphors, or by other training-related means such as internships, work-study programs, buddy systems, mentoring, and job rotation [31]."

Similarly, the students in the interviews described this type of understanding as both apparent and lacking from their formal education. They recognize that each person develops a set of values and beliefs before coming to the university setting, which serves as a guideline for their own set of ethics. These values and beliefs become transparent during the engineering ethics courses. Most develop their stances through implicit means as they bring to bear familial, cultural, and religious beliefs and values:

> *I guess that's just something that everyone builds on their own as they get older, right? Like, the way I was raised like, like, what I guess what I was taught as a kid is like right or wrong, and that carries through to the now.* -Junior, Aerospace Engineering

For one, students recognize the personal nature that comes with sharing one's own ethical stance, particularly those of the professors who are seen as neutral entities within higher education [20]:

> *[S]ome students are assholes and I feel they'd [professors] rather dodge that whole argument.* -Junior, Aerospace Engineering

However, there is a consensus among the students that they want the personal connections and anecdotes included in their conversations with professors. As Polanyi states, "We become aware of our operation of it [tacit knowing] only in the silencing of a noise [30]" :

> *[P]robably just be more upfront about it. Like, it's always just kind of skirted around like you'll talk about it a little bit. It'd be cool if a professor just sat down and asked like how you just asked me like, what's the difference for me? Between Lockheed Martin and Boeing, if someone just taught us, all the students, and was like, "Where do you draw your line?"* - Senior, Aerospace Engineering

> *I think to talk more about it and what to do and what not to do as an engineer, because that's not really covered. It's more assumed that you just need to do the math right, instead of…they never go past if you do the math wrong. It'll just blow up like an engine or something. They only talk about that kind of, like, very technical things,..they never go that extra step and I think that it would be nicer. It's like if they taught people, "Hey, you as an engineer in the future need to learn this so that this won't happen."* -Senior, Mechanical Engineering

Another form of tacit knowledge for undone ethics is that because ethics involves a personal set of values, it can't be taught but instead is something each person carries. As each person has their own set of ethics, engineering ethics is difficult to transfer due to the nuances of each person's ethical values. Thus, ethics is unteachable because you either have it or you don't:

> *A lot of the ways that ethics get involved in that class aren't really with a traditional way. It's more you realize that it's an ethics sort of thing. There isn't a lesson plan where they're like, 'Oh, this is an example of ethics'. It's more they explain, like, an aspect of communication or engineering and you realize, 'oh, like, that is kind of like an ethics thing'.* -Freshman, Computer Systems Engineering

Since these conversations are not occurring in the engineering classroom, the students learn ethics through various implicit means. Some of the tacit knowledge comes through implicit learning during COVID-19 and online learning:

> *Yeah, because I know other people at other schools and I've read some articles about you that have these kind of [situations for online proctoring of tests] "Hey is it okay if I cry on camera?" because you know, if you're recording there are people proctoring online and they're like, "Oh, you need to make sure you show your desk."* -Sophomore, Mechanical Engineering

> *[W]earing masks and getting vaccinated is kind of like it's our social duty to ensure that we're protecting ourselves where we can have a normal life. Everyone can do their thing normally but we still ensure that everyone else is safe. Right, so that's our duty socially that we are to follow these guidelines.* -Freshman, Chemical Engineering

Another form of tacit knowledge comes from informal discussions with peers and friends:

> *I talked to some of my AERO [aerospace engineering] friends and they're going to work for, like the Lockheeds, the Raytheons, and stuff. They're always talking about the idea of blood money, of being paid to make things that are going to corrupt people or kill people. And they seem kind of okay with the fact that it was gonna happen anyway, or that it was*

> *for the greater good. I was pretty opposed to that idea and they seemed more okay with it.* -Senior, Civil Engineering

> *I've talked to a few of my friends about it. But outside of that, no, never in, like, a professional setting*. - Junior, Aerospace Engineering

> *I don't think that was covered there either. So not only that, I can think of the only times when students try to discuss it within themselves, I've seen some of them unfolding in some Discords I'm in. I see people talking about a variety of things. Usually, things related to, like, Apple or one of the big companies or cases and stuff. They happen but hadn't been too directly taught and brought on*. - Junior, Computer Science

Some of the ways that students learn on their own about ethics are through various non-academic situations they faced or heard about occurring on campus:

> *A lot of these things are not okay in terms of how administration treats our Black and Latinx students … How are the ethics run behind the scenes?* -Senior, Environmental Engineering

> *I believe that it was also posted on Reddit, in regards to a student's mental health situation here at the campus. [J]ust the way the mental health center here at [university] dealt with that situation in what we thought was just horrible the way that that happened, and the way that occurred... And in terms of that situation, it was a disgusting violation of ethical boundaries when it comes to mental health.* -Junior, Nuclear Engineering

In several cases, students discussed how their interview with our researcher was the first instance of critically thinking about ethics in engineering. This research project aimed to understand how students view ethics on their own terms while acting as a minor intervention. For several students, the interview was one of the first instances where they were asked to think about ethics outside the classroom concerning their engineering education.

With the tacit knowledge form of undone ethics, there are many ways that students implicitly learn and develop their own set of ethics. However, this rarely occurs in the classroom through embodied learning experiences or environments due to the structure of engineering education institutions. So there is no explicit learning of ethics in engineering education but rather left for the student to decipher and interpret independently. Their own life experiences become the foundational texts from which their ethical developments emerge.

Conclusion

From these interviews, there is explicit student interest in learning about engineering ethics, but the apparent disinterest from professors in discussing the topic hinders the impact of engineering ethics. For many of the students interviewed in this study, the interview itself was one of the first real conversations they had regarding ethics as an engineer. It is evident that students develop their stances through implicit means as they bring to bear familial, cultural, and religious beliefs and values. Ethics are learned outside of the classroom, through conversations with friends and acquaintances, engagement with news media, and, increasingly, social media. Perhaps rather, we should meet these students in informal or extracurricular spaces than force it into the engineering curriculum. In fact, one club at the campus focuses specifically on issues surrounding scientific and technical ethical conundrums, fostering a space for these conversations.

So why should engineering educators continue to ascribe great importance to engineering ethics? It is to make sure the engineers we develop are not mindless robots, but members of society who learn and formulate critical thinking skills to inform their decisions. As engineers, they will guide the future of technological advancement, infrastructure, cybersecurity, and sustainable energy. If we continue to produce engineers whose ethics are "undone" (or even "underdone"), for whom ethical considerations do not inform their decisions in design, implementation, and upkeep, we will find the very engineers that continue to form barriers for people of color and other minorities to entering engineering, and those who consider blood money to be good money.

Limitations

While various narratives came through from the interviews with engineering students, student involvement was limited to those who have access to their university's Discord servers online. Due to COVID-19 regulations, most interviews occurred online over Discord or in-person with COVID social distancing practices in place. As a result, interviewees had to have access to the internet and Discord accounts.

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