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Exploring the Ethical Perceptions of First Year Engineering Students: Public Welfare Beliefs, Ethical Behavior, and Professional Values

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Exploring the Ethical Perceptions of First-Year Engineering Students: Public Welfare Beliefs, Ethical Behaviors, and Professional Values

In the engineering ethics education literature, there has recently been an increasing interest in longitudinal studies of engineering students' moral development. Understanding how first-year engineering students perceive ethics can provide baseline information critical for understanding their moral development during their subsequent journey in engineering learning. Existing studies have mainly examined how first-year engineering students perceived the structure and elements of ethics curricula, personal ethical beliefs, pregiven ethics scenarios, institutional ethical climates, and particular political ideals (e.g., fairness and political involvement). Complementary to the existing studies, our project surveyed how first-year engineering students perceived public welfare beliefs, examples of (un-)ethical behaviors in engineering, and professional ethical values. Specifically, we adopted part of the well-known instrument developed by Erin Cech to assess how students perceived public welfare beliefs. An important goal of replicating Cech's work is to examine whether students from a *different* cohort (i.e., 18 years after the cohort in Cech's study, and from a more specialized institution than those in Cech's study) hold different public welfare beliefs. We invite engineering educators to carefully examine how *temporality* might matter when considering the connections between previously conducted studies with their own ongoing projects. Our survey also asked students to provide an example of unethical behavior in engineering and possible ethical problems they anticipate in their future careers. Finally, we asked students to list three most important values for defining a good engineer. Such a question on professional ethical values responds to a gap in the engineering ethics literature, namely, that engineering students' perceptions of professional virtues and values are not sufficiently addressed (especially among first-year students). This paper is part of a larger project that compares how students develop moral reasoning and intuition longitudinally across three cultures/countries: the United States, Netherlands, and China. We hope that findings in this paper can be useful for engineering educators to reflect on and design subsequent ethics education programs that are more *responsive* to students' backgrounds and needs when they start their first year in engineering programs.

Introduction

Most engineering programs in the United States and other Western countries, such as Australia, have created first-year engineering programs dedicated to teaching fundamental engineering competencies and cultivating a passion for the engineering profession among students. These programs often adopt engaged pedagogies that integrate technical and non-technical (e.g., ethics and communication) competencies into the curriculum. A major goal of such an integrative approach to engineering education is to present students with a more holistic vision of the engineering profession, and communicate to students that skills necessary for good, responsible engineering are integrative by nature. Therefore, it is relatively natural that instructors often assess the efficacy of these pedagogies in their classes in terms of how these pedagogies affect students' ethical perceptions and the development of their ethical competencies. As a result, some first-year engineering instructors have developed research studies that have specifically examined the ethical perceptions of first-year engineering students.

Additionally, in the engineering ethics education literature, there has been an increasing interest in longitudinal studies of engineering students' moral development. Understanding how first-year engineering students perceive ethics can provide baseline information critical for understanding their moral development during the rest of their journey in engineering learning. Existing studies have mainly examined how first-year engineering students perceive the structure and elements of ethics curricula, personal ethical beliefs, pregiven ethics scenarios, institutional ethical climates, and specific political ideals (e.g., fairness and political involvement). Complementary to the existing studies, our project surveyed how first-year engineering students perceived public welfare beliefs, examples of (un-)ethical behavior in engineering, and professional ethical values.

This paper is part of a larger project that compares how students develop moral reasoning and intuition longitudinally across three cultures/countries: the United States, Netherlands, and China. It reports some preliminary data collected from first-year engineering students enrolled in a small R1 university in the Rocky Mountain region. We hope that findings in this paper can be useful for engineering educators to reflect on and design subsequent ethics education programs that are more *responsive* to students' backgrounds and needs when they start their first year in engineering programs.

Literature Review

The existing literature on the ethical perceptions of first-year engineering students has mainly examined how they perceive the structure and elements of ethics curricula, personal ethical beliefs, pregiven ethics scenarios, institutional ethical climates, and specific political ideals (e.g., fairness and political involvement). In general, there are two reasons for examining the ethical perceptions of first-year engineering students.

First, most engineering programs, especially those in the United States, often include an introduction to engineering course where students are expected to learn about *integrative* contexts of engineering and develop a passion for the engineering profession. Therefore, ethics, along with communication and other "non-technical" skills, are integrated into these introductory

classes. It is natural for instructors to assess how students perceive ethics before and after ethics modules. Second, an increasingly number of engineering education researchers take a more holistic approach to understanding how engineering students develop their moral identity and moral reasoning skills across their four-year learning experience. Their longitudinal studies often need to start with surveying first-year students and collecting baseline data.

Freyne, Abulencia, and Draper (2010) have examined first-year engineering students' perceptions of pregiven, contemporary ethical issues. Students were asked to read summaries of two distinct points of views of ten contemporary engineering ethics cases (they were all "macro ethics" cases, or ones about the ethics of technology) (Herkert, 2005). They were then invited to indicate where they stood, relative to two different views of each case. Students all came from an introduction to engineering course and, before taking the survey, they had all attended modules related to ethics, such as those on history of engineering, engineering ethics, ethical theories, and the National Society of Professional Engineer's (NSPE) code of ethics. They found that the particular cases students were interested in and found important to the society were related to students' career choices. Those students who provided "neutral" responses (or did not provide clear ethical judgments on these cases) to the ethics cases showed changes in viewpoint change after participating in those modules.

Stappenbelt (2013) conducted a survey among first-year engineering students to study how they perceived their personal ethical beliefs in relation to the professional ethics requirements of the Institute of Engineers Australia (IEAust). Students were provided with a list of preexisting unethical acts (developed in a previous study by other scholars, which were closely associated with the code of ethics of the IEAust) and asked to rate and rank these unethical acts. Students were capable of recognizing the ethical problems in most of these acts. The three most unethical acts rated by students were: "passing blames for errors to an innocent co-worker," "claiming credit for someone else's work," and "divulging confidential information."

Bennett, Maynard, Kapoor, and Kaur (2014) employed the Engineers Australia (EA) graduate competencies as a framework to code and analyze first-year engineering students' reflective essays after they participated in in-class workshops on the work and life of engineers. They found that, in general, first-year engineering students lacked awareness of aspects of professional ethics. Elements such as ethical conduct and professional accountability only constituted 8% of the total responses among all students. Compared to local Australian students, international students perceived a much greater gap between their own attributes and those of an engineer.

Berg, Lee, and Buchanan (2020) studied how students perceived a first-year engineering course, which included curriculum elements related to social justice, social responsibility, and ethics. Specifically, they assessed how such a curricular experience affected (1) students' views of community service and social responsibility; and (2) their views of themselves as engineering professionals.

An increasing number of longitudinal studies in engineering ethics education have examined the ethical perceptions of first-year students, in order to acquire baseline information for understanding students' moral development throughout their journey in engineering learning. For instance, Fuentes, Warnick, Jesiek, and Davies (2016) employed various existing, validated

instruments to survey first-year engineering students at four US institutions. These survey instruments focused on assessing (1) students' engineering ethics knowledge; (2) their perceptions of justice beliefs, political and social involvement, considerations in engineering work, and social responsibilities of engineers; (3) their moral attentiveness and engagement; and (4) the ethical climates of institutions. Most of these surveys asked students to respond to *predetermined* self-report statements or scenarios, rather than inviting them to openly share their own moral experience or values.

In summary, most existing studies on the ethical perceptions of first-year engineering students have employed predetermined ethics statements, scenarios, codes of ethics, and instruments to elicit student responses. It would also be worthwhile to investigate how students perceive ethics in the engineering profession *without* providing them with predetermined frameworks or resources. One strength of such an approach is that it can generate insights into the personal ethical values and dispositions students bring to engineering programs.

Methods

This paper only reports findings from three questions of a larger survey administered to first-year engineering students during their first semester at a small size, R1 engineering institution. In total, after cleaning the data, we received 86 valid responses (33% female), with a mean age of 19.7 years old. The three questions analyzed and discussed in this paper are:

1) What, in your opinion, makes a successful engineering career? Rate the importance of each category below ("1– not important"; "5 – very important")
    - professional and ethical responsibilities
    - understanding the consequences of technology
    - understanding how people use machines
2) Give an example of an unethical behavior in engineering/regarding technology
3) List three values that you think are the most important for defining a good engineer

The first question was adopted from a well-known study by Erin Cech (2014) to assess how students perceived public welfare beliefs. An important goal of replicating Cech's work is to examine whether students from a *different* cohort (i.e., 18 years after the cohort in Cech's study, and from a more specialized institution than those in Cech's study) hold different public welfare beliefs. For comparison, Cech's study was 326 valid responses (46% female) across four institutions. We invite engineering educators to carefully examine how *temporality* might matter when considering the connections between previously conducted studies with their own ongoing projects. The second question asked students to provide an example of unethical behavior in engineering. Finally, we asked students to list three most important values for defining a good engineer.

Findings

Public Welfare Beliefs

We compared our results with those from Cech's (2014) work. To assess whether there were differences between the results from Cech's (2014) study and those here, Welch's independent t-tests were carried out, comparing mean responses between the two samples (Table 1). The results of these tests were statistically insignificant, providing no evidence for differences between the results of Cech's (2014) study and those here.

Table 1 Students' public welfare beliefs (compared to Cech's study)

	Cech	*Current*	*Cech versus current*	
	M (SE)	*M (SE)*	*Difference*	*p-value*
Professional/ethical responsibilities	4.291 (.044)	4.279 (0.071)	0.012	0.886
Consequences of technology	4.384 (.042)	4.465 (0.069)	-0.081	0.320
How people use machines	4.268 (.036)	4.244 (0.080)	0.024	0.786

In general, the mean values of all three items in our study were quite close to those in Cech's (2014) study. In both our sample and that of Cech, students rated the item "consequences of technology" as more important than the other two items. In both studies, students indicated that these three items were quite important for a successful engineering career. These results further confirm Cech's findings, from a study conducted almost 18 years ago.

Ethical Behaviors

We received 85 valid responses to question #2 "give an example of an unethical behavior in engineering/regarding technology" and 1 student response was invalid (the response was "n/a"). We coded students' responses and identified five categories of unethical behaviors mentioned in their responses (see Table 2). The most typical category of unethical behaviors is "negative impacts of technology." Most of the responses under this category were concerned with either intentionally designing technologies to harm people or using technologies to serve bad ends. Quite a few students mentioned how tech companies might develop AI-enabled technologies or apps that violate human rights, such as privacy.

Table 2 Categories of typical unethical behaviors in engineering identified by students

Category	*Description*	*Frequency (Percentage)*
Negative Impacts of Technology	Engineers intentionally design technologies that will bring negative consequences to the public (e.g., physical and psychological harm, privacy breaches, social injustices and discrimination, etc.)	40 (47.06%)

Inaction	Engineers choose to not take any actions that otherwise could potentially prevent the public from being harmed.	17 (20.00%)
Dishonesty	Engineers intentionally hide information about potential risks for or harms to the public, lie to the public, or fabricate data in engineering practice.	16 (18.82%)
Cutting Corners & Profit Seeking	Engineers "cut corners" for the sake of reducing costs and maximizing profits while overlooking public safety.	9 (10.59%)
Corporate Values & Social Reputation	The public perceive certain values (sometimes can be ethically problematic) as central to some corporations. Corporations also generate certain social reputation (sometimes can be negative) in their interactions with their customers and the public.	3 (3.53%)

Professional Values

We generated a word cloud to describe the most frequently mentioned words in students' responses to the three values defining a good engineer (DePaolo & Wilkinson, 2014) (Figure 1). This word cloud was generated at https://tagcrowd.com/, and only the top 30 mentioned words are shown in the figure. Numbers included in the parenthesis after each word represent the number of times each word was mentioned in students' responses. We also grouped similar words (e.g., hardworking, hard-working, and working hard were combined into one group, "hardworking").

As indicated in the figure, the 10 most frequently mentioned values were are: honesty (18), ethical (17), creativity (13), integrity (13), intelligence (10), responsibility (10), hardworking (8), thorough (8), understanding (8), and work (7).

Figure 1 Students' responses to the three values that define a good engineer

We further coded students' responses and identified five categories of values for defining a good engineer (Table 1).

Table 3 Five categories of values for defining a good engineer

Category	*Description*	*Examples*
Professional Virtues	Virtues necessary for individual engineers to conduct engineering professionally (often these virtues serve as fundamental values for professional codes of ethics)	honesty, integrity, responsibility, accountability, humanity
Work Ethic	Values that define good employees or team members in the workplace	hardworking, thorough, dedicated, focused, cooperative, collaborative, disciplined
Technical Competence	Technical knowledge and skills that are necessary for engineers to efficiently complete assigned tasks and solve problems in practice	engineering knowledge, problem-solving, intelligence, technical skill, efficiency, goals-oriented, technological consequences
Professional or "non-technical" skills	Other "non-technical" knowledge and skills necessary for engineers to deliver their work in the practice	communication, teamwork, leadership, innovation, critical and independent thinking, curiosity, flexibility, rationality

Interpersonal predispositions	Tendencies or "predispositions" that are critical for managing the relationships between engineers and people they serve	empathy, justice, open-minded, caring, compassion, awareness, thoughtfulness

Discussion and Conclusion

One of the major findings of Cech's (2014) work was that engineering students in their first year often demonstrated higher interest in engineering ethics and public welfare than four years later, when they were about to graduate from engineering programs. Our results confirmed the first part of this finding. 18 years after Cech's study, relatively strong public welfare beliefs among first-year engineering students have not changed, at least based on the limited data analyzed here. Our future work aims to examine: (1) whether Cech's finding could be further supported in cross-cultural contexts (i.e., whether such a finding holds at our non-US research sites in the Netherlands and China); and (2) whether four years later we will see a decrease in students' interest in public welfare, as Cech observed in her study.

Compared to existing studies discussed in the literature review, this project did not employ any pregiven ethics scenarios, codes of ethics, or frameworks to examine first-year engineering students' ethical perceptions. Our goal was to use open-ended questions to elicit students' *natural* responses, or values they bring to engineering programs. Nevertheless, students in this study identified five major categories of unethical behaviors in engineering. Interestingly, without knowing the classic distinction between "micro ethics" and "macro ethics" from the literature (Herkert, 2005), most of the responses covered issues that belong to the two kinds of ethical issues: "inaction," "dishonesty," and "cutting corners and profit seeking" can be considered typical micro ethical issues, whereas the "negative impacts of technology" are connected to macro ethical issues. Nevertheless, engineering ethics scholars may feel concerned that our survey question itself provided some hint that the unethical behavior examples we were interested in would include both micro ethical and macro ethical issues (in question 2 "engineering" mainly referred to professional ethical issues or "micro" ethical issues whereas "technology" were mainly connected to social and ethical impacts of technology or "macro" ethical issues). It is unclear whether first-year engineering students at least in this study were clear about the distinction between engineering and technology or "macro" *vs.* "micro" ethical issues.

Among responses under the "negative impacts of technology," many students mentioned two kinds of ethical issues that have not been well addressed in engineering ethics textbooks and modules: (1) the ethical issues arising from the development and deployment of AI-enabled technologies; and (2) social justice, diversity, and discrimination concerns in engineering design. We suggest that one potential resolution for addressing Erin Cech's concern about moral disengagement could be to further integrate and expand discussions of these issues in subsequent science and engineering courses after the first year.

It is interesting, and yet unsurprising, to see that quite a few typical concerns in engineering codes of ethics, such as loyalty, only working in areas of competence, conflict of interest, and

bribery, did not appear in students' examples about unethical behaviors. In future studies in engineering programs, it is critical to cultivate students' awareness of and sensitivity to these issues.

The values students deemed important for defining a good engineer covered a wide range of categories, including not only professional virtues, work ethic, and technical competences, but also "non-technical" skills and interpersonal predispositions. These values are important for engineering educators to be aware of. At the very least, because engineering educators should reflect on the extent and ways in which their engineering curricula provide opportunities for students to further explore and practice values, given that first-year engineering students already think that these values are critical for becoming a good engineer.

Taking a closer look at the values in student responses, a group of values tended to be related to the rationalist, meritocratic image of the engineering profession. These values include intelligence, efficiency, and diligence (Cech, 2013). Engineering educators might want to explore opportunities in their classes to challenge and critically examine these concepts. Values in the category "work ethic," such as hardworking, dedicated, focused, and discipline, are particularly interesting and deserve more systematic investigation, since it is unclear where students developed a perception of these values as critical for a successful engineer – e.g., whether the view that "successful engineers" are hard workers comes from social media, parents (who might also be engineers), or somewhere else. It is also crucial to investigate how these work ethic values affect engineering learning experiences and the ways these values (if not critically examined) could potentially contribute to a (mistaken) meritocratic assumption: If one simply works hard enough, then one can be a good engineer. In other words, if one is not successful in engineering learning, then that means the person is not working hard enough, for instance, rather than that unjust social structure associated with engineering education prevent one from succeeding.

In summary, this paper has explored how first-year engineering students perceive public welfare beliefs, ethical behaviors, and professional values. These preliminary findings will be helpful for further improving the first-year and entire engineering curriculum, to better meet students' increasingly diverse needs and cultural backgrounds. A more fundamental, and yet challenging, question is how to design more engaging learning experiences, by leveraging passions, values, and interests in public welfare beliefs that *already* exist among first-year engineering students. It might not be strange to expect that students' interests in ethics and social responsibility decrease during their four years of study, if such interests are neglected during their second, third, and fourth years, when students tend to learn *decontextualized* engineering science theories.

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