Exploring the Perceptions of Professional Values among First-Year Engineering Students: A Cross-Cultural Comparison

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***Abstract*— In the engineering ethics education literature, there has recently been 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 perceive the structure and elements of ethics curricula, pregiven ethics scenarios, what personal ethical beliefs and specific political ideals they hold (e.g., fairness and political involvement), and institutional ethical climates. Complementary to existing studies, our project surveyed how first-year engineering students perceive professional ethical values. Specifically, we asked students to list the three most important values for defining a good engineer. This question responds to a gap in existing engineering ethics literature that engineering students' perceptions (especially first-year students) of professional virtues and values are not sufficiently addressed. We argue that designing effective and engaged ethics education experiences needs to consider the professional values perceived by students and how these values are related to the values communicated in the engineering curriculum. This paper is part of a larger project that compares how engineering students develop moral reasoning and intuition longitudinally across three cultures/countries: the United States, Netherlands, and China. We hope that findings from this paper can be useful for engineering educators to reflect on and design subsequent ethics education programs that are more responsive to students' perceptions of professional values when beginning an engineering program.**

Keywords—engineering ethics, culture, professional values,

I. Introduction

Most engineering programs in the United States and elsewhere have created programs for first-year engineering students, dedicated to teaching fundamental engineering competencies and cultivating a passion for the engineering profession. 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 that skills necessary for good, responsible engineering are integrative by nature. Therefore, it is common for instructors to assess the efficacy of these pedagogies in their courses in terms of how these pedagogies affect students' ethical perceptions and the development of ethical competencies. As a result, some first-year engineering instructors have developed research studies that specifically examine the ethical perceptions of first-year engineering students.

Additionally, in the engineering ethics education literature, interest in longitudinal studies of engineering students' moral development has grown. Understanding how first-year engineering students perceive ethics and understand ethical issues can provide baseline information critical for understanding their moral development during the rest of their education. Existing studies have mainly examined how first-year engineering students perceive the structure and elements of ethics curricula, pregiven ethics scenarios, what personal ethical beliefs and specific political ideals they hold (e.g., fairness and political involvement), and institutional ethical climates. Complementary to existing studies, our project surveyed first-year engineering students' perceptions of professional 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, the Netherlands, and China. It reports preliminary data collected from first-year engineering students in two of the three countries: the U.S. and Netherlands. We hope that in addition to

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helping build a body of literature that tracks longitudinal moral development of engineering students, that the findings of this paper can provide useful input for engineering educators. Such initial insights into engineering students' perceptions of professional values can help educators design or revise ethics education programs to be more responsive to students' backgrounds and needs when they start their first year in engineering programs.

II. 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). For instance, Fuentes, Warnick, Jesiek, and Davies (2016) employed various existing, validated instruments to survey first-year engineering students at four US institutions [1]. 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.

A major justification for exploring how engineering students perceive professional values is that dominant ideologies such as technocracy and meritocracy generated in the history of Western engineering tend to disengage engineers from reflecting on the sociopolitical nature of their identities and practices [2],[3]. Dominant approaches to engineering education provide limited opportunities for students to reflect on their own values, meaning, and commitment that will impact their long-term professional development [4],[5].

Philosophers of technology have argued that design as an activity central to the engineering profession is not value-free and values and emotions are integral for engineering decision-making [6]. Therefore, sensitivity toward values should be part of the development of professional identities of engineering students. Ethicists and engineering educators have developed pedagogical tools such as ethics autobiographies to help students develop capacities to reflect on their own values [7]. Others have proposed lists of professional values deemed critical for competent and ethical engineering practice [8]. Nevertheless, very few studies in engineering education have yet provided empirical evidence on how engineering students perceive professional values and whether the professional values students perceive as important for engineering practice vary in different cultures.

In summary, from a methodological perspective, 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.

III. Methods

This paper reports findings from one open-ended question of a larger survey administered to first-year engineering students during their first semester of undergraduate engineering education. We asked students the following question: **please list three values that you think are the most important for defining a good engineer.**

This open-ended question allowed students to answer freely, and without conforming to predetermined frameworks, cases, or terms. We surveyed students from institutions in the United States, the Netherlands, and China but this paper reports on responses from the U.S. and Netherlands. All surveys given to the students in the U.S. were given in English. Students in the Netherlands were given the survey randomly in Dutch or in English[1].

We received responses from two US institutions. In this paper, we only report responses from one institution. At this institution, we received 86 valid responses. Most students provided three values which made the total number of value terms or phrases 246. In comparison, we received 40 valid surveys in Dutch and 48 valid surveys in English for a total of 88 Netherlands surveys. While most students gave three responses, a few gave only one or two. In total, the combined surveys yielded 252 terms or phrases important for defining a good engineer. All of the Dutch responses have been translated to English for comparison and analysis.

In total, we received, 174 valid surveys combined from the U.S. and the Netherlands. From these, we received a total of 498 values defining a good engineer.

IV. Findings

Most responses were in the form of single word adjectives (e.g., thoughtful), nouns (e.g., honesty), verbs (e.g., striving for innovation) or phrases (e.g., out of the box). We grouped similar words (e.g., hardworking, hard-working, and working hard were combined into one group, "hardworking"). For the sake of brevity, in the following we use Dutch' to refer to responses from both the English and Dutch surveys of students in the Netherlands.

A. Coding

In order to compare responses across represented countries, we coded students' responses and identified five categories of values for defining a good engineer. These categories are defined below in Table 1.

TABLE I. Five categories of values for defining a good engineer

Category	***Description***	***Examples***
1-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

[1] Dutch students were asked to "Noem drie waarden die volgens u het belangrijkst zijn voor het definiëren van een goede ingenieur."

Category	*Description*	*Examples*
2-Work Ethic	Values that define good employees or team members in the workplace	hardworking, thorough, dedicated, focused, disciplined, passion, resourcefulness, loyalty, obedience
3-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
4-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
5-Interpersonal Dispositions	Tendencies or "predispositions" that are critical for managing the relationships between engineers and people they serve	empathy, justice, open-minded, caring, compassion, awareness, thoughtfulness

We then used the preliminary categorization to group responses from the two countries. The distributions across these categories are displayed below in Table 2.

TABLE II. DISTRIBUTIONS ACROSS 5 CATEGORES FOR STUDENTS FROM US AND NL

Category	*US Responses*	*NL Responses*
Professional Virtues	31.70%	31.75%
Work Ethic	10.57%	17.86%
Technical Competence	20.73%	22.62%
Professional or "non-technical Skills	23.17%	21.43%
Interpersonal Dispositions	13.82%	6.35%

Students from both the US and Netherlands provided answers across all five categories. In both cultures, most responses were related to Professional Virtues. In the US context, the least represented category was Work Ethic, whereas in the Dutch context the least represented category was Interpersonal Dispositions.

In both two cultures, with nearly one third of the responses, **Professional Virtues** was best represented amongst the student responses. Interestingly, students from both the two cultures shared some most frequent responses such as honesty, ethical/ethics, responsibility, and integrity. Nevertheless, students from the Netherlands mentioned the value "safety" more frequently (mentioned eight times) than American students (only mentioned once).

Another interesting finding was that in the Dutch data there were more responses that used phrases instead of single words to describe Professional Virtues than in the US data. In general, we clustered these Dutch terms and phrases together. One important example of this kind of clustering was the many responses making explicit mention of best outcomes or consequences, e.g., "knowing the impact of what they develop/design," "estimating consequences," and even "Makes decisions based on maximizing net good in the world." These responses, especially the last response, have clear ethical relevance. Compared to the US responses, Dutch responses demonstrated a more consequentialist thinking when articulating their professional virtues.

The second category, **Work Ethic**, received the lowest number of responses from American students and the second lowest number of responses from Dutch students. Under this category, both American and Dutch responses shared some key work ethic values such as hardworking, perseverance, discipline, trustworthiness, and truthful. In comparison, Dutch responses tended to have a greater diversity of examples. For instance, some examples that appeared in Dutch responses were not found in American responses were: passion, reliability, resourcefulness, loyalty, and obedience. In contrast, American responses under Work Ethic tended to mainly emphasize individualistic efforts in the workplace such as dedication and discipline.

In the US responses, students reported more values on **Non-Technical Competence** than **Technical Competence**. Whereas in the Dutch data, students reported slightly more values on Technical Competence than Non-Technical Competence. Among the Technical Competence responses, both cultures shared some key values such as knowledge of the field, intelligence, and problem-solving skills. One Technical Competence value appeared quite often in American responses was efficiency, whereas a Technical Competence value appeared more frequently in Dutch responses was precision or accuracy. Under the Non-Technical Competence category, American and Dutch responses were overwhelmingly similar. The only term that mentioned more in the American responses was leadership.

Under the category **Interpersonal Dispositions**, US responses had a much higher percentage (out of total responses) than Dutch responses. Nevertheless, the terms under this category in the two cultures were quite similar. Some most frequent terms in the two cultures included compassion, empathy, open-mindedness, and thoughtfulness.

TABLE III. FIVE CATEOGRIES OF VALUES FOR DEFINING A GOOD ENGINEER

Rank	*US Responses*	*US%*	*Netherlands responses (category)*	*NL%*
1	Honesty(1)	7.31	cluster - knowledge/technical expertise/skills/ability (3)	10.71
2	Ethical(1)	6.91	cluster - good consequence/outcome focused (1)	5.95
3	Creativity(4)	5.28	cluster - teamwork (4)	5.56
4	Integrity(1)	5.28	honest/honesty (1)	5.16
5	Intelligence(3)	4.07	ethics/morality (1)	5.16
6	Responsibility(1)	4.07	creativity (4)	3.97

Rank	*US Responses*	*US%*	*Netherlands responses (category)*	*NL%*
7	Hardworking(2)	3.25	thinking out of the box/innovation (4)	3.57
8	Thorough(2)	3.25	accuracy/precision (3)	3.17
9	Understanding(3)	3.25	responsible/responsibility (1)	3.17
10	Work(2)	2.85	safety (1)	3.17
		45.52		49.60

For the responses from both US and Netherlands, the top ten most frequent responses total nearly 50% of the total responses in each country (Table 3). Values in the Interpersonal Dispositions category were not presented in the top 10 terms in responses from neither of the two countries.

V. DISCUSSION AND CONCLUSION

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. This was true for both countries represented by our findings. 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.

Philosopher Michael Davis (2021) has argued that engineering itself is a globalized profession [9]. Therefore, the culture of engineering plays a more visible and dominant role than national cultures when engineers are working across cultures. The findings from this study seem to at least partly support Davis' argument as students from the U.S. and Netherlands did share many common professional values across all five categories. Nevertheless, it is worth further investigating whether such a similarity of the two cultures was due to the global nature of the engineering itself or the relative closeness of the two cultures (as compared to other non-Western cultures). A broader comparative analysis that includes non-Western cultures such as Asian and African cultures is needed.

Despite the similarities between American and Dutch responses, there were some differences between the two cultures that deserve future research. For instance, in the category of Professional Virtues, Dutch responses mentioned the value "safety" more frequently than American responses. It might be worth further exploring why Dutch students had more interest in the safety value than American students and whether and how such a difference involves in the professional formation of engineers. Also, Dutch responses demonstrated a stronger sense of consequentialist professional virtues than American responses. It might be interesting to explore whether engineering students and engineers in the two countries demonstrate different "styles" or theoretical preferences in actual professional ethical decision-making. In the category of Technical Competence, American responses tended to focus more on the value of efficiency whereas Dutch responses tended to focus more on the value of precision or accuracy. It is unclear whether such as a difference will affect how American and Dutch engineers collaborate with each other. In the category of Interpersonal Dispositions, American students provided more diverse responses than Dutch students. It is worth exploring (1) whether such a difference was due to the cultural difference in the two societies or their K-12 education practices; and (2) whether such a difference will be translated to how engineering students and engineers design and lead projects in practices.

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 [10]. These were less prominent in the Netherlands responses, though nevertheless represented. 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. That such terms were less well represented amongst Netherlands responses may indicate that the emphasis on meritocratic ideas Cech observed is specific to a U.S. context and doesn't hold more broadly.

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[11]. Our results suggest that first-year students indeed associate engineering with normative and ethically relevant terms like 'responsibility,' 'awareness of consequences,' 'integrity,' which appear with similar frequency to technically relevant terms like 'technical expertise,' 'professionalism,' or traits like 'hardworking.' Based on this first-year data, we of course cannot conclude anything yet about changes in student attitudes, although this dataset provides a helpful baseline for making such comparisons in the future.

Another factor in our analysis worth considering is the coding categories and procedures. The initial categorization was based on U.S. responses to this question, which raises questions of whether this precise schema fits Netherlands responses, or if other categorizations would offer a better fit. Additionally, since American and Dutch responses were coded respectively by two of the team members, there needs more coordination between the two coders and more quality control mechanisms are needed to ensure the reliability and consistency across the two coders (e.g., calculating interrater reliability).

In summary, this paper has explored how first-year engineering students in two countries perceive professional values associated with engineering and has provided an early, cross-cultural snapshot of what engineering students take to be important for defining a good engineer. Surveying wider swaths of engineering students, outside of the two countries represented here, is a necessary next step in this project. However, the preliminary findings presented here will be helpful for further improving the first-year and entire engineering curriculum, to better meet students' increasingly diverse needs and responding to differing 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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