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Defining a Successful Engineering Career: An Analysis of First-Year Engineering Students' Public Welfare Beliefs

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Abstract

In this exploratory, complete research paper, first-year engineering students were surveyed on their perception of public welfare beliefs, leveraging the work of Erin Cech, who published results in this area over 18 years ago. Throughout their college career, engineering students acquire a wide range of technical skills that serve as the foundation for their future professional endeavors. While technical proficiency is a core focus of engineering education, it is equally important for students to develop essential non-technical skills such as critical thinking, professional development, and ethical reasoning. These skills are vital for a well-rounded engineering career. However, an important question remains: do students themselves recognize the value of these non-technical skills? This paper seeks to answer the question: "How do first-year engineering students' perceptions of public welfare beliefs differ with exposure to ethics education and student backgrounds, mediated across cultures?" To answer this question, 1675 survey responses were collected from first-year engineering students from the US, Netherlands, and China across 7 universities from 2021-2024. Students' responses were analyzed using Multi-factor ANOVA testing, interaction plots, and hypothesis testing. Initial results suggest first-year students perceive public welfare beliefs as being more important when they have had some formal ethics education. Additionally, significant differences in the perception of public welfare beliefs were present across gender, country of origin, and religious participation.

The findings from this work can assist engineering educators in designing ethics pedagogy to be more responsive to student backgrounds and perspectives, as well as how to emphasize the importance of professional responsibility to public welfare to early engineering students. This paper is part of a larger NSF-sponsored project that intends to compare how students develop moral reasoning and intuition longitudinally across the United States, Netherlands, and China.

Introduction

Throughout the world, engineering institutions have the responsibility to equip students with the skills to solve complex problems. While there is a substantial emphasis on the technical skills that engineering students must acquire during their college education, engineers must also engage in ethical decision making. However, this poses the question: "Should ethical decision-making skills be taught in our engineering institutions?" Currently, there is limited empirical evidence that engineering ethics education is effective [1]. In addition, engineering instructors have a lack of training in engineering ethics as well as a lack of support [2]. However, if educators were given evidence of engineering ethics education being truly effective, perhaps more resources could be allocated to ensure that engineering educators have the support they need to teach ethics classes. Furthermore, engineering instructors are unsure about which methods are most effective in teaching engineering ethics to their students. Historically, if ethics are integrated into engineering curriculums, it is done in the form of a stand-alone course. [3] However, some studies have suggested that integrated modules in non-ethics classes are most effective [4]. For example, The Carnegie Foundation for the Advancement of Teaching suggests that since engineering curriculums are already so crowded, the best way to integrate ethics into classes is to increase the emphasis on professionalism into already-established learning objectives in the curriculum [5]. Other studies argue that engineering ethics should be deeply embedded into the technical

engineering curriculum, and that learning goals surrounding ethics should be explicitly outlined to students [6].

To understand which forms of engineering ethics classes are truly effective, this paper will leverage the work of Erin Cech, who developed a framework for measuring students' public welfare beliefs. In her study, she defined public welfare beliefs that would be important to students in defining a successful engineering career. The three public welfare beliefs that will be focused on in this paper include: "professional and ethical responsibilities," "understanding the consequences of technology," and "understanding how people use machines" [7]. By examining how students prioritize these various welfare beliefs, we can identify differences in their public-welfare orientations based on the type of engineering ethics education they receive. This allows us to evaluate how effective different forms of ethics education are, and if engineering ethics education is truly productive. Erin Cech's work, which was published in 2013, focused only on universities in the United States, and it measured differences in public welfare beliefs between demographic variables, such as gender, university attended, ethnicity, and income. In addition, Cech identified differences in public welfare beliefs in students over time, starting from when they were freshmen until eighteen months after graduation. This paper will focus particularly on first-year engineering students, but it will be extended to universities outside the United States. Right now, it is paramount to take a global perspective in analyzing the effectiveness of engineering ethics education, as the engineering profession is more international than it ever has been [8]. In addition, this paper will identify differences in different variables, such exposure to engineering ethics education, country of origin, gender, political affiliation, and religious participation.

Measuring the effectiveness of engineering students' public welfare beliefs is more important now than ever, which is why it is important to revisit the work of Cech over a decade later. Increasing amounts of people have been raising concerns over the unethical use of emerging technology in recent years [9]. Furthermore, the invention of generative artificial intelligence has only elevated these concerns, as there is significantly more public discourse about the ethics of advancements in technology [10]. Essentially, this paper aims to add onto the work of Erin Cech in a modern and global context to analyze the effectiveness of engineering ethics education in raising public welfare beliefs, as well as measuring new demographic differences.

Methods

Participants and Survey

Initially, 3678 surveys were collected across the United States, Netherlands, and China from 2021-2024. Of these surveys, 2003 were removed due to a lack of consent, not meeting the age criteria, submitting invalid responses, or incompleteness. The first two questions of the survey asked students: "Do you consent to have your data included as part of this research study?" and "To participate in this survey, you must be 18 years or older." Students who indicated on the survey that they did not consent to their data being included in the research and students who were under the age of 18 had their responses omitted from the survey data. After these surveys were omitted, 1675 surveys remained from first-year students across 7 universities worldwide. Of the 1675 usable surveys, 1122 surveys came from the United States, where 1040 surveys came from the University of Pittsburgh, and 82 surveys came from the Colorado School of Mines. 166 usable surveys came from Delft University in the Netherlands. The remaining 387 surveys came from China from the following universities: Shanghai Jiao Tong University, Shandong University, Dalian University, and the Chinese Academy of Sciences. It is also important to note that

when analyzing "Gender," student who answered "Non-binary/third gender" or "Prefer not to say," as these responses amounted to only 22 total surveys. Students were given an online survey to fill out. The survey asked them a variety of demographic and background questions. The relevant demographic questions students were asked can be seen in Table 1.

Table 1. Demographic Questions on Survey

Survey Question	Possible Responses
Have you had formal exposure to ethics education? (Multiple Options)	Yes or No. If yes, students choose from the following list: • Dedicated ethics course for technical professions • General ethics or philosophy course • Ethics content in other courses
In terms of political views, how would you characterize yourself? (Single Option)	• Very liberal • Somewhat liberal • Neither liberal nor conservative • Somewhat conservative • Very conservative
Please select the statement that best fits you. (Single Option)	• I participate in organized religious activities at least once per month • I participate in organized religious activities at least once per year • I consider myself spiritual but do not participate in organized religious activities • I do not participate in organized religious activities and do not consider myself to be spiritual • I prefer not to answer this question
What is your gender?	• Male • Female • Non-binary/third gender • Prefer not to say

In addition to the demographic variables that we measured for each student, each student's public welfare beliefs were measured. Leveraging the work of Cech [4], we measured students' prioritizations in public welfare beliefs by asking them: "What, in your opinion, makes a successful engineering career?" From this question, students were given three options of public welfare beliefs, and they were told to rank the options based on how important they felt that public welfare belief was. The three public welfare beliefs provided to the students were: "Professional and Ethical Responsibilities," "Understanding the Consequences of Technology," and "Understanding How People Use Machines." The students ranked the importance of each public welfare belief on a 0-4 scale, with "0" indicating they believe the public welfare belief is not important, and "4" indicating they believe the public welfare belief is very important. A summary of this question is provided in table 2.

Table 2. Public Welfare Questions on Survey

What, in your opinion, makes a successful engineering career?	
Professional and ethical responsibilities	Not important (0) … Very important (4)
Understanding the consequences of technology	Not important (0) … Very important (4)
Understanding how people use machines	Not important (0) … Very important (4)

All results were compiled together and analyzed based on demographic differences the students indicated in the survey. The results were analyzed non-parametrically, given that the data follows a non-normal, categorical fit. Mann-Whitney tests were used to conduct hypothesis testing on the effect of different exposures to ethics education and gender on students' public welfare beliefs. Kruskal-Wallis tests were utilized to analyze the effects of country of origin, political affiliation, religious participation, and number of ethics courses on students' public welfare beliefs. Lastly, an odds ratio for each of the demographic variables was calculated using ordinal logistic regression. As defined by the National Institute of Health (NIH), an Odds Ratio is "a measure of how strongly an event is associated with exposure" [11]. The higher an Odds Ratio between an exposure and an event is, the higher likelihood the event will occur, given that exposure. In this context, a higher Odds Ratio of a certain demographic variable would mean that a student is more likely to prioritize a specific welfare belief.

Analysis and Results

Professional and Ethical Responsibilities

After careful analysis of the responses of the "Professional and Ethical Responsibilities" public welfare belief responses, it was found that the significant factors increasing a student's prioritization in public welfare beliefs include exposing students to ethics education in non-ethics classes, gender, country of origin, religious participation, and the number of ethics courses they have taken. The p-values from each test are shown in Table 3.

Table 3. P-values for Mann-Whitney Tests for 'Professional and Ethical Responsibilities'

Demographic Variable	p-value
Technical Ethics	0.10
General Ethics/Philosophy	0.51
Integrated Modules in Non-Ethics Classes	<0.001*
Gender	<0.001*
Country of Origin	<0.001*
Political Affiliation	0.08
Religious Participation	<0.001*
Number of Ethics Courses	<0.001*

Note: An Asterisk indicates the p-value is significant at α=0.05

Out of the three choices of exposures to ethics education students were given, the only type of ethics education that was significant in increasing students' prioritizations of professional and ethical responsibilities were integrated modules in non-ethics classes. Additionally, the more ethics classes students are exposed to, the higher prioritization they will have for professional and ethical responsibilities. Female students were much more likely to rank the "professional and ethical responsibilities" public welfare belief much higher than male students. The prioritization of this public welfare belief also varied by the student's country of origin. Students from the United States prioritized this public welfare belief the most, followed by Chinese students, then Dutch students. In addition, the more a student participates in organized religious activity, the higher prioritization they have for professional and ethical responsibilities.

In addition to the hypothesis testing conducted for each demographic variable, odds ratios were calculated. The values of each odds ratio are shown in Figure 1.

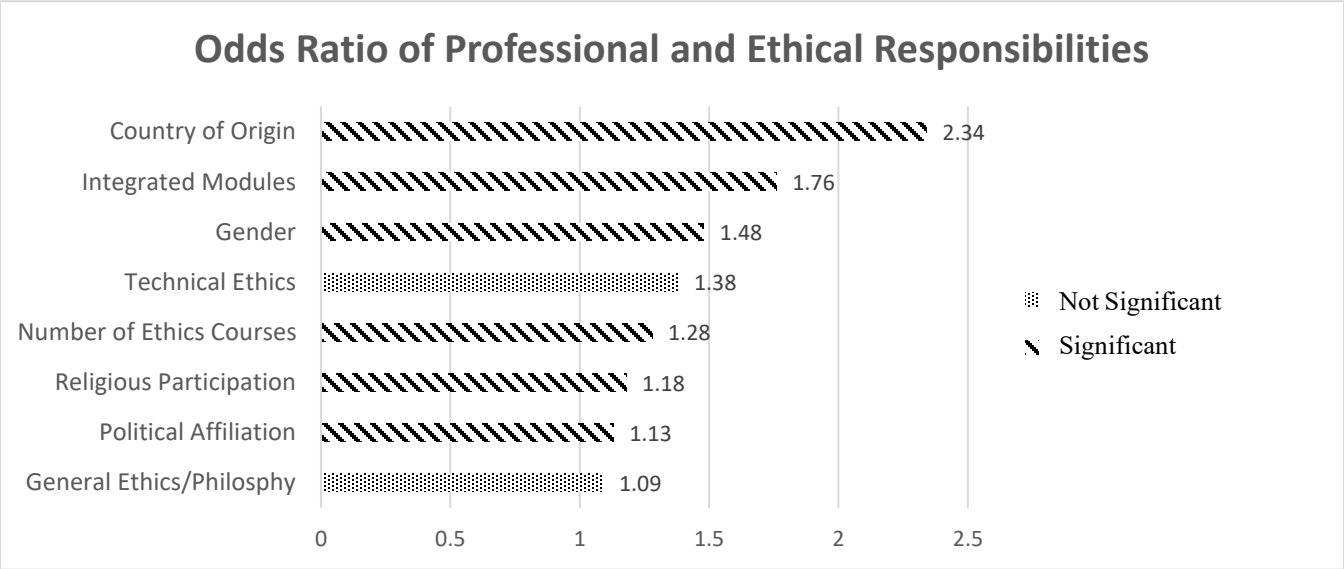

Figure 1. Odds Ratio of Professional and Ethical Responsibilities

Nearly every demographic variable was significant in increasing a student's prioritization of the public welfare belief, "Professional and Ethical Responsibilities." However, the only two variables that were not significant were exposure to a technical ethics course and exposure to a general ethics/philosophy course. The variable with the largest odds ratio was a student's country of origin. The odds of a student ranking "Professional and Ethical Responsibilities" higher is 2.34 times more likely if the student is from the United States compared to China. The odds of a student ranking "Professional and Ethical Responsibilities" higher is 2.34 times more likely if the student is from China compared to the Netherlands.

Understanding the Consequences of Technology

After testing the demographic variables against students' ranking of public welfare beliefs, the p-values of each test were calculated. These values are shown in Table 4.

Table 4. P-values for Mann-Whitney Tests for 'Understanding the Consequences of Technology'

Demographic Variable	p-value
Technical Ethics	0.47
General Ethics/Philosophy	0.81
Integrated Modules in Non-Ethics Classes	0.045*
Gender	0.21
Country of Origin	<0.001*
Political Affiliation	0.44
Religious Participation	0.25
Number of Ethics Courses	0.46

Note: An Asterisk indicates the p-value is significant at α=0.05

As shown in Table 3, many of the variables were not significant in increasing a student's prioritization of understanding the consequences of technology. The only variables that showed a significant difference in students' prioritizations of this public welfare belief were whether they had been exposed to integrated modules in non-ethics classes and their country of origin. Students ranked this public welfare belief much higher if they had received formal exposure to ethics education in the form of integrated modules. In addition, the average ranking of the public welfare belief "Understanding the Consequences of Technology" followed the same pattern as the "Professional and Ethical Responsibilities" public welfare belief, where US citizens prioritize this public welfare belief highest, followed by Chinese students, then Dutch students.

In addition, an odds ratio was calculated for the prioritizations of this public welfare belief based on demographic variables, which are shown in Figure 2.

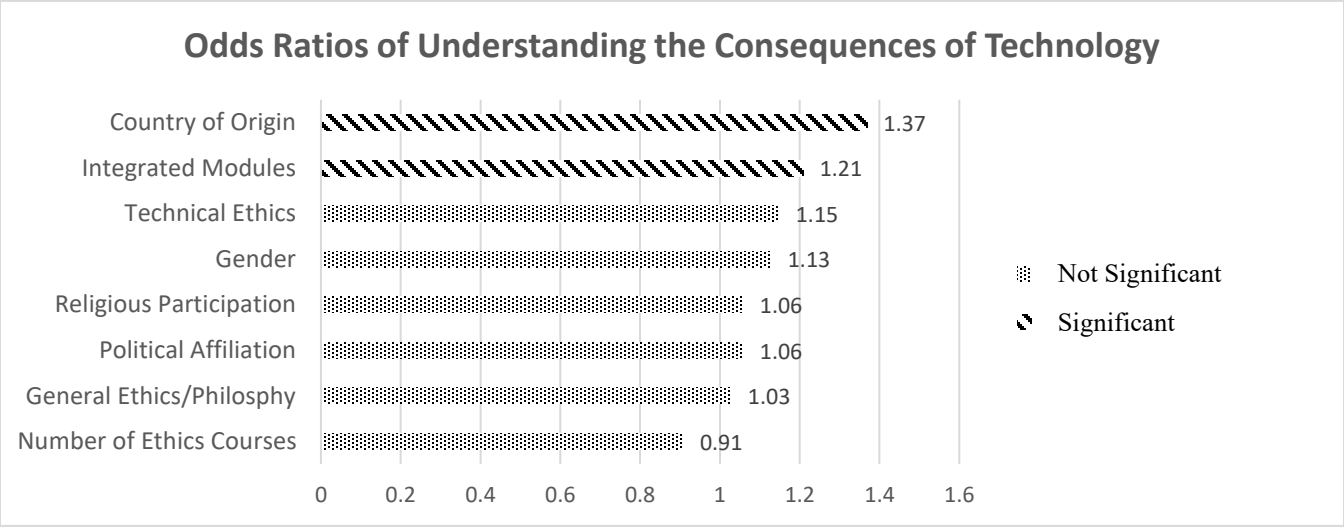

Figure 2. Odds Ratio of Understanding the Consequences of Technology

The only variables that had a significant odds ratio were a student's country of origin and whether they had received integrated ethics modules in non-ethics classes. This is consistent with the Mann-Whitney and Kruskal-Wallis testing that had been conducted prior to the odds ratios. All other variables' odds ratios were not significant, implying that there is no association between each of the demographic variables and a student's prioritization of understanding the consequences of technology.

Understanding How People Use Machines

Lastly, differences in students' prioritizations in the public welfare belief, "Understand How People Use Machines" were analyzed. After conducting the appropriate tests, the p-values were calculated for each variable that was tested. These p-values are shown in Table 5.

Table 5. P-values for Mann-Whitney Tests for 'Understanding How People Use Machines'

Demographic Variable	p-value
Technical Ethics	0.04*
General Ethics/Philosophy	0.84
Integrated Modules in Non-Ethics Classes	<0.001*
Gender	0.52
Country of Origin	<0.001*
Political Affiliation	0.88
Religious Participation	0.02*
Number of Ethics Courses	<0.001*

Note: An Asterisk indicates the p-value is significant at α=0.05

As shown in the table, the variables that were significant in increasing a student's prioritization of understanding how people use machines include exposure to a technical ethics course, exposure to integrated ethics modules in non-ethics classes, country of origin, and religious participation. If a student has exposure to either a technical ethics course or an integrated ethics module, they will rank this public welfare belief higher than students who have not been exposed to these types of ethics education. Following a similar pattern as the other two public welfare beliefs, students in the United States prioritize understanding how people use machines the most, followed by Chinese students, then Dutch students. In addition, there is a positive association between a student's religious participation and how much they prioritize understanding how people use machines. As they participate more in organized religious activity, they rank this public welfare belief much higher than those who are less active in organized religion.

Furthermore, an odds ratio was calculated for each of the demographic differences between students. These results are shown in Figure 3.

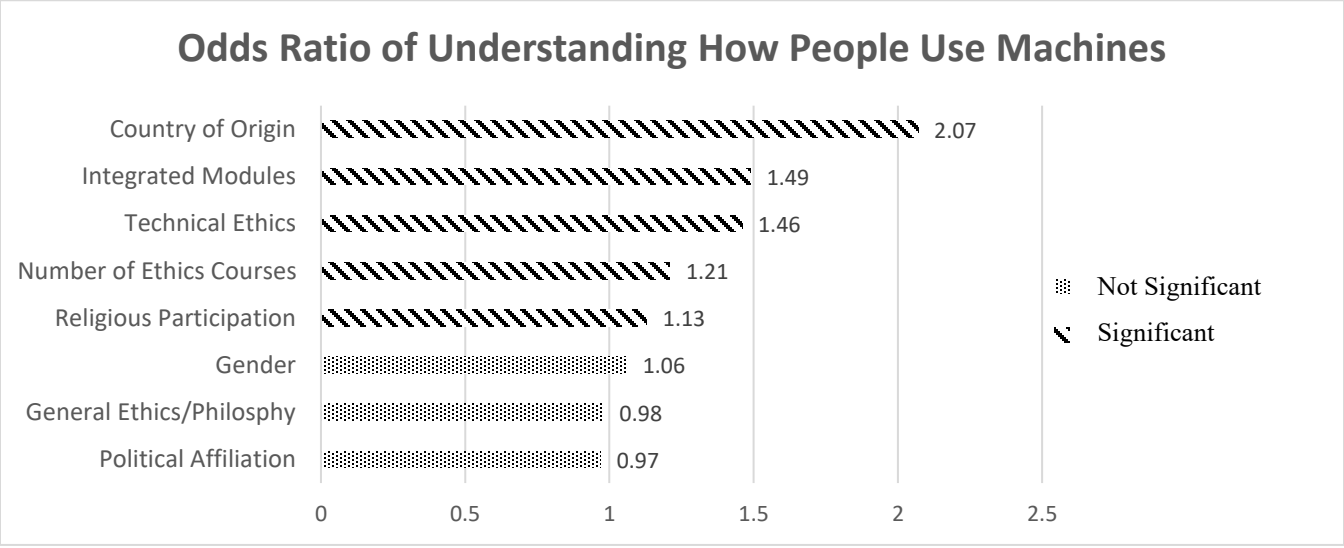

Figure 3. Odds Ratio of Understanding How People Use Machine

As shown in Figure 3, each variable's odds ratio was significant except for gender, exposure to a general ethics or philosophy of course, and political affiliation. The rest of the variables show that a student is more likely to prioritize that public welfare belief based on their country of origin, if they have been exposed to a technical ethics course or an integrated module in a non-ethics class, or their participation in organized religious activity. These results are consistent with the previous Mann-Whitney and Kruskal-Wallis tests that were conducted.

Discussion, Conclusions, and Future Work

This research study reveals a great deal of information about the differing prioritizations in public welfare beliefs across first-year engineering students. It reveals the significant and non-significant methods of ethics education in raising students' awareness in these beliefs, as well as which demographic variables may play a role in their beliefs. This study was able to conclude which variables are effective in raising students' awareness Cech's three public welfare beliefs: "Professional and Ethical Responsibilities," "Understanding the Consequences of Technology," and "Understanding how People Use Machines." In terms of Professional and Ethical Responsibilities, the significant variables in raising this public welfare belief were if the student had taken a non-ethics class with an integrated ethics module, and the number of ethics classes the student had taken. In addition, a student's gender, country of origin, and religious participation played a part in determining how much a student prioritizes this public welfare belief. For the public welfare belief, "Understanding the Consequences of Technology," variables that were found to be significant in raising a student's prioritization include whether a student had taken a non-ethics class with an integrated ethics module and the student's country of origin. All other measured variables were not significant in raising a student's prioritization of understanding the consequences of technology. Lastly, the significant variables in raising a student's prioritization of the public welfare belief, "Understanding how people use machines" were whether the student had taken a technical ethics course, or a non-ethics class with integrated ethics modules. This prioritization was also dependent on the amount of ethics classes taken by the student, as well as their country of origin. Universally, there was no effect on how a student thinks about public welfare beliefs based on whether they had taken a general ethics or philosophy course. A student's political affiliation also had no effect.

This study can help educators make decisions on which types of classes to integrate into their engineering curriculums. Engineering educators can and should attempt to teach ethics education to their students, as it is important to the betterment of society and the welfare of the public. If educators are to attempt to teach ethics education to their students, the most effective form of ethics education is integrating ethics modules into non-ethics classes. Out of all the types of ethics classes taken, integrated ethics modules in non-ethics classes were effective in raising the public welfare beliefs of students in every belief tested. If ethics modules are integrated into non-ethics classes, perhaps we can foster a new generation of ethically minded engineers, helping us pursue a more ethical world. However, educators must consider the demographic variables that may affect a student's prioritization of these beliefs. Perhaps future studies of this topic could

measure the interaction between the types of ethics classes taken by students and their demographic differences.

While this study reveals important information about the effectiveness of engineering ethics education integration, it is somewhat limited in its scope. A more thorough analysis of differences in country of origin could be conducted across the globe, not just in the three countries analyzed in this study. In addition, a paired study should be conducted to students before and after they have been exposed to engineering ethics education to see a more direct effect of different types of ethics education on engineering students. Lastly, this study is limited in the fact that all the collected data was self-reported by students. Perhaps a future study could explore these effects on public welfare beliefs using more objective data.

Acknowledgements

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