What Role do Civil Engineering Students See for their Profession in the COVID-19 Response?

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Abstract

Engineering education typically focuses on technical knowledge rather than ethical development. When ethics are incorporated into curriculum, the focus is usually on microethics concerning issues that arise in particular contexts and interactions between individuals, rather than macroethics that address broad societal concerns. The COVID-19 pandemic has presented a unique opportunity to assess macroethical understanding because unjust social, economic, and environmental systems have been brought to the forefront of the response. In this study, we aim to understand students' awareness of unjust systems and the ethical responsibilities of engineers. At the beginning of the pandemic in the United States, in April 2020, we deployed a survey to undergraduate engineering students at two universities. We asked students to explain what they perceived to be the role of the engineering profession in response to the global COVID-19 pandemic. This paper focuses on 84 responses of undergraduate civil engineering students across two universities. We used qualitative analyses (deductive and inductive coding) to explore responses in which macroethics are present and those responses that they are not. We then use inferential statistics to test whether the presence of macroethics in responses is associated with sociodemographic factors. We show that there are statistically significant differences across student responses given certain sociodemographic factors. Responses from women focused more on macroethics as compared to responses from men. There was also a difference in responses between the universities surveyed, potentially capturing that institutional differences may impact students' macroethical development. Implications from this study include recommendations on curricular content and identifying which student demographic groups would benefit most from intentional macroethical content in coursework. Further it is worth exploring in the future if increasing diversity and representation of women in engineering may impact the engineering industry's focus on macroethics based on these findings.

Introduction

COVID-19 Global Pandemic

The COVID-19 pandemic has broadly impacted communities and industries. Civil engineers, who design, build, and maintain public infrastructure systems, play a key role in protecting public health. By maintaining water distribution systems, they can ensure communities have access to clean water for hand washing, an essential aspect of keeping oneself safe from infection [1]. Public transportation systems saw a drastic decrease in usage, while simultaneously needing to provide reliable, safe access for essential workers [2]. Building systems have also gained attention, as indoor ventilation has become a focal point of maintaining healthy spaces [3]. All of these systems can impact public health; however, this connection is often overlooked or misunderstood [4]. Vulnerable populations, such as lower-income or ethnically minority communities, especially rely on civil engineers to design and maintain resilient systems to keep them safe and healthy [5]. While much of an engineer's work is technically focused, it is important for civil engineers to recognize their impact on their community's health and safety.

Engineering Ethics

We frame our analysis using microethics and macroethics to understand civil engineering's role in the pandemic. Microethics, which is typically emphasized in the engineering profession, focuses

largely on individual decision-making and interpersonal relationships [6]. The American Society of Civil Engineers focuses on this particular aspect in Canon 4 of its Code of Ethics—it discusses the importance of avoiding conflicts of interest and acting "as faithful agents or trustees" to clients and employers [7]. These considerations are examples of microethics concerns. In contrast, discussion of macroethics, which focuses on broader societal issues like impacts of climate change or issues of social justice, was traditionally overlooked in engineering contexts [8]. Macroethics is concerned with the impact of engineering work on society. It is imperative for civil engineers to engage with macroethics due to the unique position they have in impacting society through their work [9]. In 2017, the American Society of Civil Engineers recognized that the industry's priorities were shifting, focusing more on macroethics issues. They added Canon 8 to the ASCE Code of Ethics, stating that "engineers shall consider the diversity of the community, and shall endeavor in good faith to include diverse perspectives" [7].

Undergraduate engineering programs often do not make the distinction between microethics and macroethics in their ethics lessons. Rather, individual conduct (microethics) is typically the focus of engineering ethics [8]. Additionally, much of the existing literature focuses on research ethics [10], [11] or privacy issues [12], [13]. Due to the focus on microethics in classrooms historically, there may be room for changes moving forward, with a new focus on engineering macroethics.

We know from history that global tragedies can impact engineers' priorities. For instance, after the terrorist attacks on September 11, 2001, many engineers shifted focus to study building technologies and how they can design future buildings to better withstand threats [14]. Additionally, after devastating earthquakes in Alaska in 1960 and 1964, the state adopted the International Building Code, increasing building safety standards. Almost sixty years later, these building code revisions are credited with zero fatalities and minimal building damage after a massive 7.0 earthquake in 2018 [15]. We expect the COVID-19 global pandemic to have a similar influence on civil engineering education and the engineering industry. We posit that engineering programs will incorporate more macroethics—emphasizing the importance of collective action to protect vulnerable populations and populations inequitably burdened or impacted. In this study, we seek to understand the views of undergraduate civil engineering students at this unique time during the global COVID-19 pandemic.

Undergraduate Engineering Survey

In April 2020, shortly after the onset of the COVID-19 pandemic in the United States, we deployed a survey to undergraduate engineering students at two public universities in different states. The survey was intended to evaluate students' understanding of engineers' ethical roles in society. Due to the timing of the survey (just weeks after classes turned virtual), we used this opportunity to gain an understanding of students' views of a civil engineer's role during the COVID-19 pandemic. This exploratory research seeks to understand students' perspectives. Here, we analyze the students' responses to the question "*How can engineers address the COVID-19 pandemic?*" We first evaluated whether or not each response could be categorized as macroethics. We used qualitative analysis, both deductive and inductive coding [16], to find emergent themes within this macroethics context. We then explore a range of sociodemographic information, seeking to understand which factors might be associated with macroethics responses using chi-squared testing [17].

Methods

Survey Development

In April 2020, we deployed a web-based survey to undergraduate students in the civil engineering departments at two public institutions, one in the Southern United States and one in the Midwestern United States. Students were recruited through emails sent by civil engineering professors and any participation was voluntary. The survey questions were developed by a team of graduate research assistants and reviewed by a team of experts in a range of disciplines: civil engineering, philosophy, political science, and anthropology. The survey was administered through the Qualtrics Survey Software [18] after it was pilot tested by a small group of undergraduate and graduate civil engineering students to check for accessibility and clarity; these responses were not included in the final sample. The survey included two components that are relevant to this study: (1) the question, "How can engineers address the COVID-19 pandemic?" and (2) a range of sociodemographic information. The COVID-19 question was an open-ended text response and the sociodemographic questions included multiple choice responses, including a "prefer not to respond" option. There were approximately 25 questions relating to students' backgrounds, including university, age, gender, religiosity, political affiliation, and race/ethnicity.

Qualitative Coding of survey responses

Open-ended responses to the COVID-19 question underwent qualitative analysis using NVivo [19]. Here, we used deductive coding, beginning with two categories: microethics and macroethics, based on the distinction developed by Herkert [6]. Following that, the data underwent secondary inductive coding [16] to allow relevant thematic codes to emerge, resulting in the coding dictionary shown in Table 1. Notably, a single response may be coded to multiple thematic codes simultaneously [20]. For instance, one respondent wrote, "faster PPE creation [and] design structures that address changing needs". This response would be coded to both "design/manufacture PPE and medical equipment" and "improve building design". All responses were coded by a single researcher and then validated through inter-coder reliability checks [21], with agreement of 89% and 91% of codes.

Quantitative Analysis to compare sociodemographic factors

We performed hypothesis testing, specifically chi-squared tests [17], to assess the associations between the survey responses (i.e. macroethics or non-macroethics) and sociodemographic factors (e.g. university, major, gender, religiosity, political affiliation, race/ethnicity). While microethics was included in the initial coding process, for this paper, we exclusively discuss macroethics due to the lack of focus on this aspect of ethical training in undergraduate engineering education.

Table 1. Macroethics coding dictionary used for analysis

MACROETHICS CODE	DEFINITION	EXAMPLE EXCERPT
Address Environmental Issues	Find technical solutions to reduce environmental impacts	*"Since animal health clearly has an impact on human health, it should be more of an incentive to protect our waters and air for all inhabitants of the earth"*

Build Medical Facilities	Design/build temporary or permanent medical facilities to ease the burden on the healthcare system	*"Help build temporary hospitals"*
Contribute to Economic Growth	Contribute to protecting the economy for people to provide for their families	*"Create economic growth to assure people/parents can maintain a steady income"*
Create Safe Work Environment for Others	Create a safe working environment where people are protected from harmful exposures	*"Encourage social distancing on job sites and possible create a schedule work to minimize close contact between laborers"*
Design/Manufacture PPE and Medical Equipment	Design/manufacture PPE and medical equipment to help protect people from the virus	*"By engineering new, cost efficient and effective ways to make masks"*
Improve Building Design	Improve design of buildings for increased health and safety	*"Engineer healthy building systems to prevent diseases from being spread to all occupants"*
Improve Virus and Vaccine Research	Contribute to research on the virus properties and potential vaccine	*"Analyzing ways to interpret data to help track the spread of the virus"*
Maintain Infrastructure Systems	Maintain public infrastructure to ensure people have access to safe water and other public needs	*"Making sure that clean water is being provided to all communities"*
Prioritize Welfare of Vulnerable Populations	Consider vulnerable populations in decision-making and ensure equitable access to needs during the pandemic	*"Developing ways to care for the homeless like handwashing stations"*

Results

Coding Frequencies

The survey yielded 84 complete and valid responses to the COVID-19 question. Seventy-five percent of these respondents provided a response that included a macroethical concept. Table 2 summarizes the coding frequencies of sub-codes; notably, the frequency refers to the number of unique respondents for each code—i.e., a single response could not be coded multiple times to a single category. However, some responses were coded to multiple categories. Twenty-four percent of responses that included macroethics focused on improving building design. Twenty percent of macroethics responses focused on building medical facilities, and another 20% focused on creating safe work environments. Five respondents stated that civil engineers should not be involved in the COVID-19 pandemic response at all.

Table 2. Thematic codes and frequencies of occurrences in survey responses

Code	Frequency
Address Environmental Issues	2
Build Medical Facilities	11
Contribute to Economic Growth	5
Create Safe Work Environment for Others	11
Design/Manufacture PPE and Medical Equipment	9
Improve Building Design	13
Improve Virus and Vaccine Research	9
Maintain Infrastructure Systems	7
Prioritize Welfare of Vulnerable Populations	6

Chi-Squared Testing

Chi-squared tests were used to find associations between macroethics responses and sociodemographic factors. These tests were exploratory, intended to test many factors for significance. Table 3 shows several sociodemographic factors that were tested, with reported pvalues. The tests revealed that university and self-identified gender were associated with a student's response to the question "How can engineers address the COVID-19 pandemic?" Specifically, students who self-identified as women considered components of macroethics in their responses more often than those who self-identified as men. Students at the Southern institution mentioned macroethical considerations more frequently than the institution in the Midwest. Chisquared tests for other sociodemographic factors, such as class year, race, religiosity, and political leaning, were not found to be statistically significant.

Table 3. Results of the Chi-Squared Tests

		Macroethics	Non-Macroethics	Total	p-value
Gender	Woman	32	8	40	
	Man	23	18	41	
	Total	55	26	81	**0.0212**
University	Southern	39	14	53	
	Midwestern	17	14	31	
	Total	56	28	84	**0.0786**
Class Year	Sophomore	15	4	19	
	Junior	20	13	33	
	Senior	21	11	32	
	Total	56	28	84	0.3964
Race	White	37	20	57	
	Non-White	19	8	27	
	Total	56	28	84	0.6202
Religiosity	More religious	16	11	27	
	As religious	14	3	17	

	Less religious	27	13	40	
	Total	57	27	84	0.2787
Political Leaning	Conservative	11	7	18	
	Moderate	13	7	20	
	Liberal	29	14	43	
	Total	53	28	81	0.8927

Discussion

The survey results demonstrate that in the midst of the COVID-19 pandemic, civil engineering students are in fact considering macroethics. Due to the lack of emphasis placed on macroethics in undergraduate education [6], we might not have predicted this high rate of response. Students mentioned a range of macroethical concepts when asked how their profession—civil engineering—could help in the COVID-19 response (e.g., "making sure that clean water is being provided to all communities", "designing buildings that prevent the spread of infectious diseases"). We can also see from this that students do want to use their civil engineering professional assets to help in times of crisis. We can see that students are thinking broadly about the societal impacts of their profession and the role they may play in protecting the public during a pandemic.

Response Differences between Universities

The hypothesis tests revealed statistically significant associations between the type of response (presence of macroethics) and university that the students were attending. The Southern institution's civil engineering students who participated in the survey referenced macroethics in their responses more often relative to the Midwest institution's civil engineering students. There could be a range of reasons for this difference, including course curricula, university culture, or geographical influences.

Potential differences are especially interesting in light of the COVID-19 pandemic response. Because the sample size was rather small, it is possible that the students who participated from the institution in the Southern US happened to be taking specific courses at the onset of the pandemic that focused on macroethics, while perhaps the specific students from the institution in the Midwest were not. Ethics is often taught differently in engineering programs at different universities, in different departments, and even in different courses. Typically, professors can choose how much time is invested in ethics education in their courses, as they determine the specific content that is covered (as long as it meets the course objectives). Some engineering professors choose not to include macroethics (broad societal issues) in their course content, and rather focus exclusively on the technical aspects of the course objectives [22]. It is important to note that perhaps the difference here is not between universities, but perhaps between specific programs or courses. This is something that is worth further research—whether a single class can shift this mindset amongst students or if it does need to be woven consistently throughout the curriculum.

Due to the timing of the survey and that this was a current event, students who referenced macroethics in their responses may have been participating in class discussions (virtually) about the role of engineers during survey deployment. Many professors devoted time in their courses, or at least for a few minutes before each lecture, to check in on students' well-being and discuss the status of shut-downs. These macroethics discussions are important because if students participated in courses that focused on ethics in an engineering context, they may be more capable of referring back to these lessons once they are working in industry. For instance, a transportation course might discuss the positive impact of accessible public transportation in low-income communities [23].

This macroethical concept emphasizes the importance of engineering for vulnerable populations. Once these students graduate to work in industry, they may be more likely to consider these populations in their design or development, leading to more equitable projects.

In light of the COVD-19 pandemic, engineering courses could even pivot to include current issues in their discussions of engineering ethics. For instance, public transportation availability has changed due to social distancing and stay-at-home orders with those essential workers who rely on public transportation for their work commute often facing decreased availability and altered routes [24]. This lack of access has a disproportionate impact on low-income communities and as such is important for engineers to understand so that they can consider these communities more often in their work. Students who discuss issues arising in disaster contexts such as public transit mentioned above in the classroom, connecting technical lessons to societal applications, are more likely to make this connection outside of class [25]. If students routinely discuss social inequities while in a supportive learning environment, they might be more likely to draw on this experience in times of crisis, like the COVID-19 pandemic.

Response Differences across Genders

A statistical association was revealed between responses including macroethical themes and the students' self-identified gender, women versus men. Notably, other gender identities were not present at high enough frequencies to test. Women respondents were more likely to reference macroethical issues in regards to civil engineers' roles in the pandemic response versus men. We may have expected similar results even if this survey had been deployed prior to the global pandemic. Research shows that women tend to score higher than men in ethics evaluations [26], [27]. Additionally, Ritter [26] found that in an ethics intervention training, women's ethical understanding improved greater than the men involved in their study. Lund [27] further found that women's ethical judgment increased with age and education level. While we cannot currently make recommendations for improving ethical judgment amongst specific gender identities, we can infer that as the number of women in engineering increases over time, the ethical understanding within the industry as a whole may very likely increase.

For instance, a 2014 study in Sweden challenged traditional snow removal practices which typically begin with highways before clearing sidewalks and local roads. Women, who more often walked, biked, or used public transportation, however, experienced more delays and injuries in these traditional circumstances. With women on the leadership team, they switched the order of snow removal—starting with walking paths, then moving on to local roads, then highways. Ultimately, the entire community experienced a decrease in hospitalizations, vehicle accidents, and delays [28]. This finding demonstrates the importance of women in leadership and decisionmaking roles. Women can bring diverse solutions to engineering problems, leading to greater impacts for the whole community. Women's tendency to lead with a more collaborative and collective approach can be translated to civil engineering work. The survey responses show that women are more likely to consider the impact of their work on others, an essential aspect of controlling the virus. In fact, all six responses coded to "prioritize welfare of vulnerable populations" were from respondents who identified as women.

This is an important result as women are still an underrepresented group in the engineering profession [29]. In fact, only 20.9% of engineering bachelor's degrees in 2019 were awarded to women [30]. Recruitment and retention of women in engineering is essential to ensuring an industry concerned with social issues and macroethical concepts. Further, the retention of

professional women in industry is essential to creating an equitable built environment based in macroethics. However, before the COVID-19 pandemic, the National Science Foundation reported that there were three times as many women scientists and engineers out of the workforce and not looking for work than there were men [30]. This is further explained by the number of women citing family responsibilities as their reason for not working—four times as many women as men [30]. As a result of the COVID-19 pandemic, this divide has continued to increase. In September 2020 alone, roughly 865,000 women dropped out of the labor force, compared to 216,000 men [31]. This dramatic departure from the workforce can be largely attributed to childcare needs [31].

Engineers should not be involved?

A small percentage of students (6%) responded that engineers should not be involved in the pandemic response (e.g. "engineers are not doctors", "ride it out"). These responses demonstrate that there may be a lack of understanding within education programs in regards to the responsibilities or capabilities of the civil engineering community. These responses in particular contradict the Code of Ethics put forth by the American Society of Civil Engineers. The preamble of this code recognizes the role of civil engineers in protecting the public, stating that engineers shall "above all else protect and advance the health, safety, and welfare of the public" [7]. This commitment to public health should be amplified in light of the COVID-19 pandemic. For instance, civil engineers play a vital role in water sanitation and distribution [32]. Throughout the pandemic, these engineers have had to adapt to changing protocols and regulations regarding social distancing or stay-at-home orders, while still maintaining this public infrastructure [33]. Perhaps there is a disconnect in some engineering programs between the technical engineering requirements and the societal context in which the work applies [34].

Conclusion

We deployed a survey in April 2020 at two public universities aimed at undergraduate engineering students. This survey was uniquely timed as it was sent to students just weeks after COVID-19 became a widespread issue in the United States and university classes began operating virtually. We asked the students, "How can engineers address the COVID-19 pandemic?" Their responses provided an opportunity for this study to evaluate their ethical understanding of engineers' roles in times of crisis. Using qualitative coding methods, we found that many respondents were concerned with an engineer's role in broad societal issues (macroethics). Students discussed the opportunities for building improvements, workplace safety, and protection of vulnerable populations. Specifically, the analysis found that civil engineering students at the university in the Southern US, compared with students at the university in the Midwest, responded with ideas that were more focused on macroethical issues. Additionally, we found that respondents who identified as women focused on macroethical concepts more often than those who identified as men. While the sample size here was rather small, it provided the opportunity for an exploratory study. In future work, we can build on these findings to gain a better understanding of the drivers of ethical understanding and behavior. By continuing to study and focus on macroethical concepts, we can ensure a more equitable future, built by engineers.

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