2023 Annual Conference & Exposition
Baltimore Convention Center, MD | June 25 - 28, 2023
The Harbor of Engineering Education for 130 Years
Paper ID #38147

Engineering ethics and the public: Impacts of a graduate-level course on students' ethical perceptions and conduct in research and professional settings (2010-20)

Frank A. Mazzola, Virginia Polytechnic Institute and State University

Frank is a PhD student in Civil & Environmental Engineering at Virginia Tech. He researches the corrosion of drinking water infrastructure, focusing on lead complexation by polyphosphate and on the impact of water treatment strategies on the galvanic corrosion of lead solder. In 2022, Frank began serving as teaching assistant for the graduate level course "Engineering Ethics and the Public," co-founded by his advisor, Dr. Marc Edwards. Frank received both his bachelor's and master's degrees in civil engineering from Virginia Tech.

Mr. Siddhartha Roy, Virginia Polytechnic Institute and State University

Dr. Siddhartha Roy is a Research Associate at the UNC Water Institute, where he conducts research at the nexus of drinking water, public health, international development and environmental justice. He received his MS/PhD in Civil/Environmental Engineering from Virginia Tech.

Dr. Marc Edwards, Virginia Polytechnic Institute and State University

Dr. Marc Edwards received his bachelor's degree in Bio-Physics from SUNY Buffalo and an M.S./Ph.D. in Environmental Engineering from the University of Washington. Dr. Edwards is currently a University Distinguished Professor, and teaches courses on engineering ethics and applied aquatic chemistry.

Engineering Ethics and the Public: Impact of a Graduate-Level Course on Students' Personal and Career Priorities and Values (2010-20)

Abstract

A graduate level three-credit elective course entitled "Engineering Ethics and the Public" has been offered by the Civil and Environmental Engineering department at Virginia Tech since 2010. The course draws on high profile case studies, both past and unfolding, to examine real-world ethical dilemmas that confront engineers and scientists in research, policy, and practice. Course alumni from 2010-2020 (n=65) were surveyed in 2021-2022 to determine their perceptions of the class and its impact on their ethical principles and conduct. Responses were compared to a control group of graduate students who were enrolled in the same department during the same time period who did not take the class (n=68). The control group placed significantly higher value on technical expertise, salaries, and work on projects for perceived job satisfaction, compared to course alumni, who placed greater value on interactions with the people whose lives their work may impact ($p<0.001$). Course alumni also were also more likely to listen to members of the public outside of their field ($p=0.040$) in considering ethical dilemmas.

Introduction

Through their work, engineers and scientists can impact the public in a positive and negative manner. The obligations of engineers and scientists in society are continually evolving and debated, including their work involving the public and marginalized communities [1]-[6]. These topics are addressed from an aspirational applied ethics perspective in a graduate-level course at Virginia Tech: CEE 5804 "Engineering Ethics and the Public" [7], [8]. The course draws on high profile case studies, both past and unfolding, to examine ethical dilemmas that confront engineers and scientists in research and practice. The course seeks to reimagine the role of ethics in the careers of engineers and to expand the notion of "ethical conduct" to include moral courage, moral leadership, and moral action, and provide students practical tools to foster a sustained connection to the public and their inner selves [9]. The class also provides practical techniques to help future engineers and scientists make themselves aware of pressures to behave unethically in the workplace.

The development of this ethics course was funded by the National Science Foundation (Grant #1135328) [7], [10] and was identified as exemplary by the National Academy of Engineering [11] and the Association of Environmental Engineering and Science Professors [12]. Faculty and students from this course have collaborated with dozens of underserved communities and helped uncover the dimensions of drinking water crises in Washington DC (2000-04), Flint, MI (2014-15), and Denmark, SC (2008-18) amongst other cities [13], [14]. Through the course, the students grapple with past and evolving ethical dilemmas and/or examples of scientific misconduct in the public eye. They also engage in semester-long research projects that include interviews with community members involved in policy, activism, science, and engineering. From Fall 2010 to Fall 2020, the course was offered 11 times to 165 students. The overall goal of this study was to evaluate the impact of this course on the students' ethical perceptions and awareness. This paper focusses on student values.

Methods

Survey

A survey instrument was developed to evaluate the impact of the ethics course, incorporating both quantitative and qualitative components, and administered online via Qualtrics® (www.qualtrics.com). The anonymous survey was offered to both alumni of the class from Fall 2010 - Fall 2020 and to a control group of Virginia Tech Civil and Environmental Engineering (CEE) students from the same time period who did not enroll in the class. A $20 Amazon gift card was offered as an incentive to those who completed the survey. The students were asked questions on their perceptions of the course and its impact on their ethical principles and conduct in research or professional settings. In this conference paper, we focus on questions related to the impact of the class on various dimensions of their careers and personal values.

Attempts were made to contact all 164 students who had completed the course from 2010-2020 (excluding alumnus of the class, author SR, who administered the survey). A total of 40% of the course alumni (n=65) completed the survey. A randomly selected population of 328 of 430 graduate students in the CEE department's Environmental and Water Resources program, who had not taken the class from 2010-2020, were also contacted as a control group. A total of 21% (n=68) took the survey. After the survey was completed, author FM, who took the course in 2020 and had also responded to this survey, was invited by authors SR and ME to collaborate on data analyses and manuscript writing.

This study has been approved by Virginia Tech's Institutional Review Board (IRB #21-502).

Statistical Analysis

All quantitative survey data was analyzed using Minitab® (version 21). Unpaired, two sample t-tests were used to determine statistical significance, with an alpha (α) of 0.05.

Results

In order to ascertain the class or graduate program's possible impact on personal values and conduct in professional settings, survey participants were asked to rank the importance of nine criteria for an "ideal engineer," from 1 as the most important to 9 as the least important (Figure 1).

Alumni (n=65) and the control group (n=67) both ranked "technical skills/expertise," "ethical behavior," and "serving society" as the top three parameters. However, ethics class alumni ranked "interactions with people whose lives you may impact" (4th) as significantly more important (p=0.008) than the control group (6th), who placed higher priority on "work on projects" and "local knowledge." Differences between the alumni and control group were not significantly different for other criteria (p>0.05).

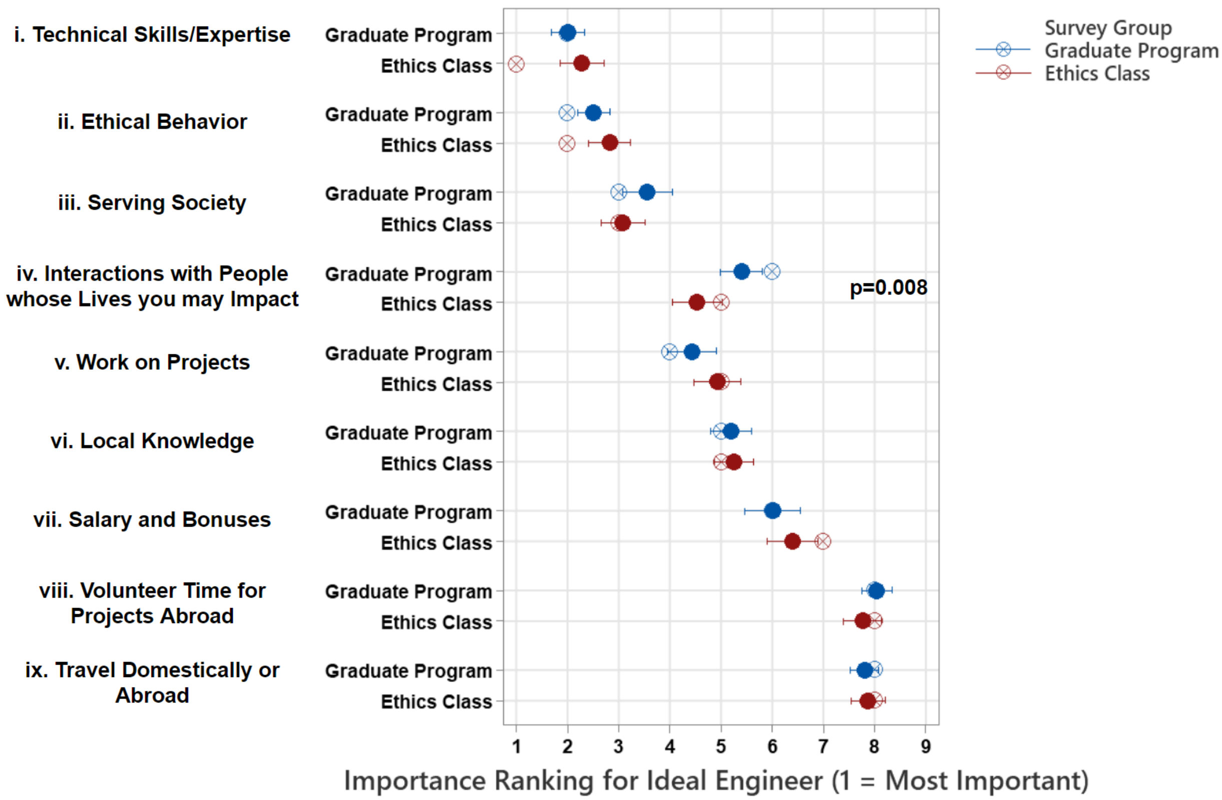

Figure 1: Ranking of Nine Parameters for the "Ideal Engineer"

When survey participants were asked to rank the importance of the same nine criteria for themselves personally (Figure 2), instead of for the "ideal engineer" (Figure 1), the most important criterion for the alumni was "ethical behavior," whereas "technical skills/expertise" was highest for the control group (n=66). The latter criterion was ranked significantly higher by the graduate program than the class alumni (p=0.021). On the other hand, ethics course alumni ranked "interactions with people whose lives you may impact" as their 4th most important value, while this criterion only ranked 6th for the control group. This difference was statistically significant (p<0.001). Course alumni ranked "work on projects" and "salary and bonuses" as the 5th and 7th most important aspects of their professional lives as engineers, which was lower than the control group (4th and 5th). The control group's rankings for these two parameters were significantly higher than the course alumni (p=0.017, p=0.033). Differences in rank order between the two groups for the five remaining criteria were not statistically significant (p>0.05).

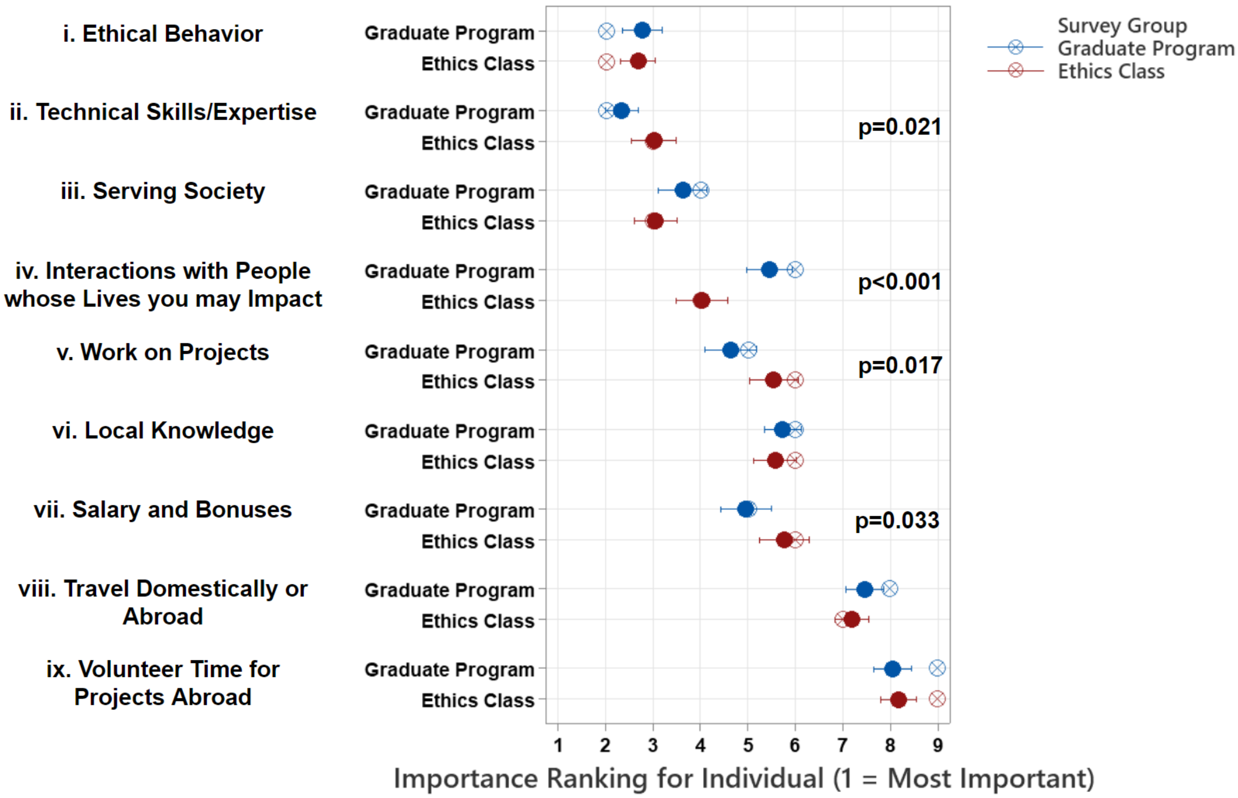

Figure 2: Ranking of Nine Parameters for "You Personally"

The widest differential between survey groups for the "ideal engineer" and "self" ranking, was for "interactions with people whose lives you may impact." (Figure 1 versus Figure 2), which course alumni considered more important over the control group. Both groups rated ethical behavior and serving society in the top three for the "ideal engineer" and themselves, and relegated travel and volunteer service to the bottom.

Course alumni (n=65) and the control group (n=68) also rated the importance of academic freedom and listening to other voices, both within and outside of their fields, on one's ability to act ethically (Figure 3). These ratings were placed on a scale from 1 to 10, with 10 being the most important. Ethics class alumni placed significantly higher importance ($p=0.040$) on listening to members of the public outside of their field ($\mu=8.62$, $\sigma=1.52$) than the graduate program control group ($\mu=8.00$, $\sigma=1.89$). On the other hand, ethics class alumni rated "academic freedom and free speech" ($\mu=8.31$, $\sigma=1.68$) slightly lower than the graduate program ($\mu=8.57$, $\sigma=1.64$). The ethics class alumni also valued listening to professionals within their field ($\mu=8.37$, $\sigma=1.60$) slightly less than the control group ($\mu=8.57$, $\sigma=1.40$). However, neither of these differences were of statistical significance ($p>0.05$).

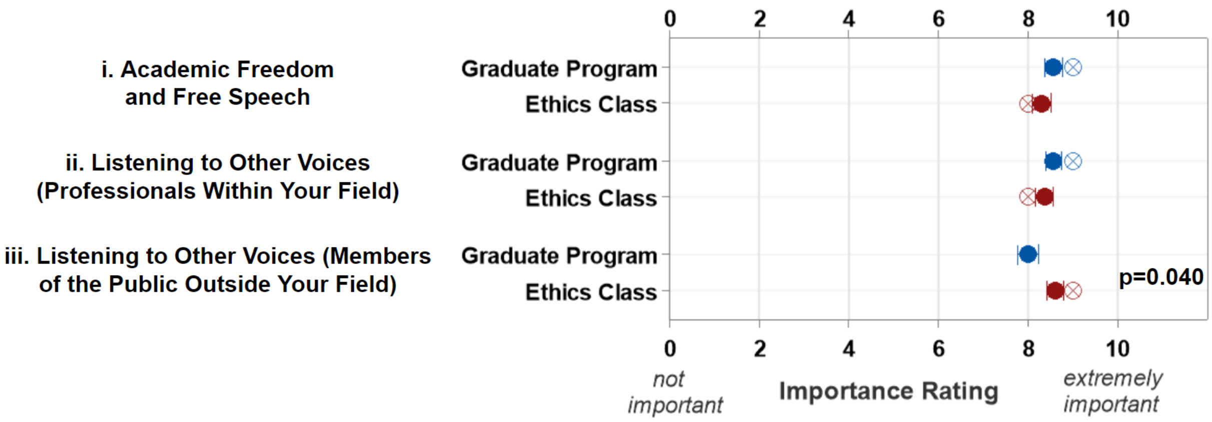

Figure 3: Importance of Various Parameters on one's Ability to Act Ethically

Discussion

Alumni of the ethics class had different priorities for their professional careers and lives as engineers and scientists (Figures 1 and 2). This may partly reflect a self-selection bias, in that students who voluntarily took a class on "Engineering Ethics and the Public" may have placed greater value on that subject matter than those in the control group who decided to take another class enhancing technical skills. Alternatively, it may reflect success in achieving course objectives (Table 1) [8], [9].

Table 1: Ethics Course Objectives for Fall 2020 Semester

Learning Objectives
1. Define unethical conduct in engineering and science
2. Discuss potential "costs" of misconduct and "benefits" of morally sound conduct
3. List personal, professional, or societal motives, other than profit, that can foster unethical behavior
4. Describe the code of ethics of at least one engineering or scientific society
5. Describe key moral theories relevant to ethical decision-making
6. Define "the public" and discuss its role in the production of technical knowledge
7. Identify skills, other than technical proficiency, that are necessary for competent practice in engineering and science
8. Describe the kind of engineer/scientist you aspire to become
9. Develop a comprehensive plan to identify ethical dilemmas in real-world cases as well as processes by which to determine preferable solutions to these dilemmas

Most notably, course alumni placed far greater emphasis on the importance of interacting with people whom their work may impact (Figures 1 and 2). This might be due to the fact that this criterion directly relates to primary course objectives. The course also incorporates case studies and guest speakers, where students are able to query citizen scientists, and observe the harm caused to the public by engineering and scientific misconduct. Furthermore, students engage in semester-long projects where they identify an ethical dilemma and conduct an interview with a stakeholder, often a member of the public who considers themselves a victim of an environmental injustice or unethical misconduct by scientists and engineers. On the other hand, graduate students who did not take the class placed a relatively greater emphasis on values such as technical skills, projects, and salaries.

Similar to the control group graduate program students in our study that favored technical skills/expertise, engineers in prior surveys placed greater value on problem solving skills than on ethical standards [15]. However, in one study when undergraduate engineering students were asked an open-ended question to describe values for a “good engineer,” the most common responses included “honesty,” “integrity,” and “responsibility” [16]. In our study, the ethics course alumni placed lesser importance on salary compared to the control group. One point of the ethics class is to discuss a correlation between salary and emotional well-being, which is significant only up to an annual income of ~$75,000 [17], which most civil/environmental engineers earn in the first 3 years of employment [18]. It might be that this and other exercises helped put the importance of salary into a new perspective.

Ethics course alumni placed significantly greater emphasis on listening to members of the public outside their field of expertise than the graduate program alumni (Figure 3). This is a targeted skill in the ethics course’s case studies and projects. The course also includes in-depth “learning to listen” exercises, with activities such as interviewing someone with a different viewpoint on a subject specifically in order to gain a deeper understanding of their position. The incorporation of listening to “community voices” in civil and environmental education has recently been associated with students reporting greater self-assessed recognition of “ethical and professional responsibilities” for engineers [19].

Further data analyses of responses to more detailed survey questions are underway and may create a more complete picture of the course’s impacts. That will include perceptions of ethical wrongdoing in the workplace, self-reported outcomes pertaining to ethical behavior in graduate school, and temporal trends over the 11 years of teaching the class. These results could be considered in creating, implementing, or improving engineering ethics curricula around the country.

Acknowledgements
This study was funded by Spring Point Partners LLC. The efforts of Dr. Yanna Lambrinidou in co-founding, co-developing and co-teaching the course from 2010-2014 are gratefully acknowledged.

References

[1] A. R. Bielefeldt, M. Polmear, D. W. Knight, N. Canney, and C. Swan, "Educating engineers to work ethically with global marginalized communities," *Environmental Engineering Science*, vol. 38, no. 5, pp. 320–330, 2021.

[2] L. Roldan-Hernandez, A. B. Boehm, and J. R. Mihelcic, "Parachute Environmental Science and Engineering," *Environmental Science & Technology*, vol. 54, no. 23, pp. 14773–14774, 2020.

[3] D. Sedlak, "Crossing the imaginary line," *Environmental Science & Technology*, vol. 50, no. 18, pp. 9803–9804, Sep. 2016.

[4] M. A. Edwards, A. Pruden, S. Roy, and W. J. Rhoads, "Engineers shall hold Paramount the safety, health and welfare of the public - but not if it threatens our research funding?," *Flint Water Study* , 10-Oct-2016. [Online]. Available: http://flintwaterstudy.org/2016/10/engineers-shall-hold-paramount-the-safety-health-and-welfare-of-the-public-but-not-if-it-threatens-our-research-funding/. [Last Accessed: 07-Feb-2023].

[5] M. A. Edwards and A. Pruden, "We helped flint residents save themselves and are proud of it—staying in our ivory tower would have perpetuated injustice," *Environmental Science & Technology*, vol. 50, no. 22, pp. 12057–12057, Nov. 2016.

[6] E. P. Douglas, J. B. Holbrook, and F. Corbo-Ferreira, "Engineering ethics education for social justice: Implementation and preliminary data," *2022 IEEE Frontiers in Education Conference (FIE)*, Oct. 2022.

[7] S. Mackay, "Virginia Tech to launch engineering and science ethics course," *Virginia Tech | Exponentially More Stories*, 11-Nov-2011. [Online]. Available: https://vtx.vt.edu/articles/2011/11/111111-engineering-marcandyannastudy.html. [Last Accessed: 02-Feb-2023].

[8] Y. Lambrinidou and M. Edwards, "Learning to listen: An ethnographic approach to engineering ethics education," *2013 ASEE Annual Conference & Exposition Proceedings*, pp. 23.860.1–23.860.6, Jun. 2013.

[9] Lambrinidou and Edwards, Engineering Ethics and the Public Course Syllabus, 2010-2022

[10] "Flint water crisis: For Young Engineers, a lesson on the importance of listening," *NSF*, 23-Mar-2016. [Online]. Available: https://www.nsf.gov/discoveries/disc_summ.jsp?cntn_id=138060. [Last Accessed: 02-Feb-2023].

[11] National Academy of Engineering, "Infusing Ethics into the Development of Engineers: Exemplary Education Activities and Programs," 2016. [Online]. Washington: National Academies Press. Available: https://doi.org/10.17226/21889. [Last Accessed: 02-Feb-2023].

[12] "AEESP award for outstanding contribution to environmental engineering & science education," *AEESP Foundation*. [Online]. Available: https://www.aeespfoundation.org/awards/outstanding-contribution. [Last Accessed: 02-Feb-2023].

[13] M. A. Edwards and S. Roy, "'Public Inspired Science' Graduate Training Program," *Online Ethics Center*. [Online]. Available: https://onlineethics.org/sites/onlineethics/files/2021-09/NAE%20Edwards%20Roy%20Submission.pdf.

[14] T. Lightner, S. Roy, J. S. London, and M. Edwards, "'Racing the sun': A narrative analysis of engineering graduate students' journeys navigating public-inspired science work," *2021 ASEE Annual Conference*, Jul. 2021.

[15] K. Anderson, S. Courter, T. McGlamery, T. Nathans-Kelly, and C. Nicometo, "Understanding the current work and values of professional engineers: Implications for engineering education," *2009 Annual Conference & Exposition Proceedings*, pp. 14.1297.1–14.1297.17, Jun. 2009.

[16] S. D. Streiner, Q. Zhu, and R. Clancy, "Proceedings of the 2022 ASEE North Central Section Conference," in *Examining the Relations between Moral Intuitions and Values among First-Year Engineering Students: Implications for Culturally Responsive Ethics Education*.

[17] D. Kahneman and A. Deaton, "High income improves evaluation of life but not emotional well-being," *Proceedings of the National Academy of Sciences*, vol. 107, no. 38, pp. 16489–16493, Sep. 2010.

[18] "Civil Environmental Engineer Salaries," *Glassdoor*. [Online]. Available: https://www.glassdoor.com/Salaries/civil-environmental-engineer-salary-SRCH_KO0,28.htm. [Accessed: 11-Feb-2023].

[19] A. Bielefeldt, "Listening to community voices as part of Ethical Civil Engineering: Experiences in civil engineering courses," *2020 ASEE Virtual Annual Conference Content Access Proceedings*, Jun. 2020.