Best 2019 PIC IV Paper : Student Views on their Role in Society as an Engineer and Relevant Ethical Issues

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Abstract

It is important that engineering and computing students are educated to understand the ethical expectations of the profession and to consider the broader impacts of their work (termed ethics and societal issues, ESI). However, assessment methods related to these outcomes that rely on Likert-type responses or structured assignments may be susceptible to social desirability or positive response bias. When prompted, students will normally agree that ethics are important and can select the correct answer for simple ESI questions. But what do engineering and computing students quickly draw to mind in relation to ESI? To explore this, students were asked to respond to two open-ended survey questions: (1) How do you view your role in society as an engineer or computer scientist? (2) List the ethical issues that you think are relevant to engineers and/or computer scientists. It was of interest to determine if student responses would vary from the beginning to the end of a term or across 15 settings where instructors had integrated content and learning goals pertaining to ESI (ranging from first-year introductory courses to courses fully focused on ethics at different institutions and among different majors). Students' open-ended responses were coded using a combination of *a priori* and emergent codes. Student responses regarding their role in society generally encompassed six theme areas (in order of decreasing prevalence): societal benefits, technology, sustainability, obligations, self, and responsibility to employer. In regards to relevant ethical issues, common themes included safety, environmental protection, and monetary trade-offs. Differences among the prevalence of particular themes across the courses may be due to differences in the interests and/or training in different majors. The very short responses from many students are somewhat troubling, given that all students should be able to readily answer these questions with more complex and detailed responses after having taken a course that included ethics content. This raises interesting issues around students' feelings about the importance of these topics, and indicates that these questions may reflect on the affective domain (e.g. value) to an equal or greater extent than the cognitive domain (e.g. knowledge, reflected in the response to Q2).

Introduction

Engineering has significant and important impacts on society, being critical to providing basic necessities (e.g. access to clean water) as well as contemporary conveniences and entertainment. While largely positive changes have resulted from the use of technology, engineers should also carefully weigh the potential for negative outcomes. The process of reasoning and judgement around the development and application of technology needs to be cultivated among engineers, and is therefore recognized among the accreditation requirements for engineering degree programs [1]. Training students to bolster their ability to recognize their role in ethics and societal issues (ESI) is therefore an important concern.

Students pursue engineering and computing majors due to a variety of motivations. Market-research conducted by the National Academy of Engineers [2] found that the message 'engineers make a world of difference' was the most appealing among all groups, and 'engineering is essential to our health, happiness, and safety' was the second most appealing statement for girls. These findings have been used to 'market' engineering for a decade, potentially drawing in a

generation of students with these perceptions of engineering. However, research has found that these 'prosocial' motivations tend to decline over time among engineering students, termed a 'culture of disengagement' [3]. These perceptions are relevant to ethics – do engineering students graduating from engineering programs feel that their greatest responsibilities are to serve the public and protect the environment (within the paramountcy clause in many professional engineering codes of ethics) or earn profit for their employers?

The assessment of students' knowledge and attitudes toward ethics and societal issues often take place in formats that limit our ability to authentically determine their views. For example, homework assignments and other graded work on ESI come with the expectation that students will discuss ethical dilemmas; they reveal little about students' attitudes about these issues. Likert-type surveys have been more commonly used to reveal students' attitudes about ESI. The extensive study by Finelli et al. [4] explored the level of students' ethical development using a 152 item Student Engineering Ethical Development (SEED) survey plus the Defining Issues Test version 2 (DIT-2). It appears, however, that this study treated ethics somewhat as a monolith and/or focused on microethical issues. This has been inferred because it was reported that the SEED survey evaluated students' knowledge of ethics using "questions like ones on the Fundamentals of Engineering Examination" (FE exam) [4, p. 475]. FE exam questions on ethics have typically been multiple choice and focused on the NCEES Rules of Professional Conduct as a code of ethics, which encompasses obligations to the public, employers and clients, and other engineering licensees [5]. These rules of conduct include no mention of an obligation to protect the environment or sustainability, which are found in other professional codes of ethics such as from the National Society of Professional Engineers [6] and the American Society of Civil Engineers [7]. Even the note on sustainability in ethics section from the 2014 version of the NCEES FE Reference Manual [8] is absent in the 2018 edition [5]. The DIT-2 test to assess students' moral judgement is not specific to engineering settings. In addition, the survey evaluated students' negative ethical behaviors by asking students to report their frequency of cheating in college. This again maps to microethical issues. However, larger societal issues (e.g. macroethics) were not clearly apparent. Students were "asked to indicate the single curricular experience they would be most likely to consider when facing an engineering ethical dilemma" [4, pg. 476]. It is uncertain to what extent the use of the term 'ethics' on the survey brought microethical, 'code'-related elements to mind for the students versus broader macroethical issues. This is perhaps predicated on how students were taught about ethics.

Relatedly, Canney and Bielefeldt [9] studied engineering students' attitudes about professional social responsibility using a survey with 50 Likert-type items. Social responsibility as defined in the instrument reflects an individual's personal feelings of their obligation to act with care toward others, recognizing the impact of their personal and professional actions on others, and motivated to help people and society including disadvantaged populations [10, p. 414]. The Ethic of Care [11-13] was part of the theoretical basis for the survey instrument, however the term 'ethics' only appeared in one of the fifty survey items [9]. However, a key disadvantage is that the 'right answer' in terms of social desirability is often quite evident or if students were prone to acquiescence response bias their true opinion would not be evident (i.e. only 12 of the 50 items were 'reverse worded').

Therefore, the current research aimed to explore students' views about ESI through open-ended questions that might be less subject to bias.

Research Questions

RQ1. How do undergraduate students view their future role in society as engineers / computer scientists? Does this change across a term due to a course with ESI content or differ across settings?
RQ2. What ethical issues do students think are relevant to engineers and/or computer scientists? Does this change across a term due to a course with ESI content or differ across settings?

If differences were found across a term or among settings, the researchers would attempt to discern whether these differences were likely due to course content (e.g. topics taught) or other factors (such as differences among disciplines or institutions).

Methods

Survey. The role in society survey question was taken from Canary et al [14]. For the majority of the settings examined, the question read: "how do you view **your** role in society as an engineer or computer scientist?" In one course where the majority of the students were believed to be non-engineering/CS students, the wording of the question was modified to: "how do you view **the** role in society of engineers?". The second question on the survey was "List the ethical issues that you think are relevant to engineers and/or computer scientists." These two open-ended response items were placed at the beginning of the survey. It was assumed that students' would be the most attentive at the start of a survey and less subject to bias in their response based on the content of other survey items, which would imply how the researchers perceived and defined the ethical responsibilities of engineers/CS. On the pre-survey, four Likert-type questions followed and the survey concluded with demographic items. On the post-survey, 36 Likert-type questions followed [15] and the survey concluded with demographic items. Among the Likert-type questions, items of interest in this study include:

- How important do you believe ethical issues are to engineering? [1 to 10 scale]
- To what level do you feel prepared to face ethical issues in your future work? [1 to 10 scale]

In addition, four items on a 1 to 7 scale queried students' self-perceptions (averaged together):

- I feel prepared to identify and critique the underlying values in engineering design solutions
- I find it easy to understand the implications of engineering solutions from an ethical and societal impact perspective.
- After working on the ethical/societal content in [course] I feel pretty competent.
- When examining the societal impacts of engineering in [course], I feel confident that I can identify possible conflicts between social, environmental and economic priorities.

All surveys began with an informed consent statement. The research was approved by an Institutional Review Board for Human Subjects Research.

Settings. As part of a larger project, settings for ESI instruction were included in the study as potential 'exemplars' of ESI teaching. Instructors completed an online survey (n=1448), and based on those responses interviews were completed where 35 settings for ESI instruction were

described in more detail [16]. From among these interviews, a sub-set of settings were selected for additional study; 11 instructors agreed to partner with our study (one with three different course settings). The characteristics of these settings are summarized in Table 1. Two additional course settings were included in the study to provide 'baseline' data, using a convenience sample of civil engineering students that generated a fairly large response rate (italicized in Table 1). Among the 15 settings, 14 were courses and 1 was a co-curricular setting (Engineers Without Borders, EWB). The courses were all "full" courses (e.g. 3 credits) with the exception of the two convenience courses. Ethics content in the courses ranged from a small amount (e.g. FY courses, engineering science and elective courses), to a moderate amount (professional issues courses, communication course), to two courses fully focused on ethics. The majority of ESI settings were in public institutions; three courses were at religiously-affiliated private institutions and one at a secular private institution. The settings were predominantly focused on undergraduate students, ranging from first-year (FY) to seniors (Sr).

Table 1. Settings for Student Assessment

ID	Institution [cc]	Course, Student Rank, Majors[%]	Topics / Pedagogy	Pre n	Post n	Pre/post response rates, %
Comm-Elect	Public, Med, R2	Intercultural Communication, Jr-Sr, eng[81]	social justice, cultural awareness, privilege, inequality / discussion, reflection	NA	16 [e]	NA / 34
EngSci-Req	Public, Lg, R1	Fluids, soph/jr, ChE[70] Bio[22]	economic, political, social, environmental tradeoffs of hydraulic fracturing / discuss contemporary controversy from multiple perspectives	NA	21 [e]	NA / 46
Eth-Gen	Public, Lg, R2	Ethical Issues, FY to Sr, eng[32]	research integrity, ethical theories, bioethics, privacy, sustainability, public health, climate change, nanotechnology / discussion, reflection	NA	25	NA / 69
Eth-Rel	Relig, Lg, R1	Ethics, So-Sr, ME[58] EE[20] Bm[8]	moral reasoning, risk, safety, bias, conflict of interest, whistleblowing, intellectual property (IP), environmental protection, legal compliance, workplace ethics, impacts of technology, big data, bioethics / discussion, case studies, current events, team projects, reflection	64	60	100 / 94
EthPrf-Rel	Relig, Lg, MS	EthProf, Sr, ME[52] EE[24] Bm[24]	workplace professionalism, code of ethics, social justice, identity, emotion / case study, discussion, reflection	21 [e]	9 [e]	62 / 26
EWB	Public, Lg, R1	EWB, all, all	cultural awareness, poverty, developing communities / PBL	3 [e]	23 [e]	6 / 46
FY-Rel	Relig, Sm, Bac	Intro, FY, all engineering	code of ethics, personal ethics, responsibility to client and employer, macroethics/case study, discussion, creative narrative of ethical dilemma	46	34[e]	96 / 71
Prf-All	Public, Lg, MS	ProfIssues, Jr + Sr, BS Eng,	ethics in design, workplace professionalism, ethical decision-making/discussion, reflection, PBL, debate	21	11[e]	75 / 39
Prf-Sr-Priv	Private, Lg, MS	ProfIssues, Sr, Civ[69] EE[25]	ethics codes, workplace professionalism, leadership / peer evaluated discussion of contemporary issue, case study, reflection journal	NA	16	NA / 50

ID	Institution [cc]	Course, Student Rank, Majors[%]	Topics / Pedagogy	Pre n	Post n	Pre/post response rates, %
Risk-Elect	Public, Lg, R1	Cost/Risk tech elective, So-Grad, Ind[3] Cv[25] CS[25]	risk, safety, uncertainty, whistleblowing, environmental protection, organizational ethics, IP / discussion, videos, current events, case studies, reflection	NA	8	NA / 89
Sci-Elect	Public, Lg, R1	Elective, FY to Grad, mainly non-STEM	energy, climate change, sustainability/lecture, discussion, group projects, discussion of contemporary controversy from multiple perspectives	NA	35[e]	NA / 40
SrDsn-Env	Public, Lg, MS	Capstone Dsn, Sr, Env[100]	workplace professionalism, code of ethics, responsibility to client and employer/ surprise ethical dilemma in context of team projects, discussion	25	15[e]	69 / 42
Sust-Elect	Public, Lg, R1	Sustainable energy tech elective, Jr+Sr, all engrg majors	energy, sustainability, LCA, environmental protection, climate change / discussion, current events, group projects, guest speakers	NA	19[e]	NA / 36
FY-Civil	*Public, Lg, R1*	*Intro (1cr), FY, Cv[100]*	*Ethics, sustainability, design*	*41[*]*	*32*	*65 /51*
Prf-Sr-Civ	*Public, Lg, R1*	*ProfIssues (2cr), Sr, Cv[100]*	*Ethics, sustainability*	*48*	*56*	*75 / 89*

[cc] Carnegie Classification information on institution
NA = Not applicable, pre survey was not administered
[*] This group not asked about 'ethical issues' on pre-survey
[e] Surveys administered electronically via Qualtrics
[1] This survey asked students about 'the role of engineers' instead of 'your role as engineers / CS"

Survey Administration. In seven courses offered in fall 2017, surveys were only distributed to students at the end of the term; in eight settings in 2018 both pre and post surveys were distributed at the beginning and end of the term. In about half of the settings, hard copy surveys were distributed to students and they were given time in-class to take the survey. In seven settings, students were provided with a link to the electronic online survey and completed the survey on their own time (noted by 'e' superscripts in Table 1). Students at the partner 'exemplar' sites were given $10 eGift cards to Amazon for completing the survey, if they provided their email address. Students at the convenience site were awarded course extra credit for participating in the survey. The number of students who completed the write-in response questions are shown in Table 1. A few students skipped one of the write-in items or completed the Likert-type items but not the open-ended questions (<5%).

Themes from Open Ended Responses. For students' view of their future role in society (RQ1), we began by using codes reported in Canary et al. [14]. These codes mapped into five primary themes, with sub-topics. Additional themes also emerged in the coding process, including sub-themes of 'societal benefits' and responsibilities to employer. Initially, the sustainability and technology themes had two sub-themes each. But upon further consideration, these areas seemed closely related and therefore only the broad theme area will be discussed in this paper. The responses across 10 settings were coded by the third author and the other 5 settings were coded by the second author. The third author negotiated the code book and themes with two additional raters for one of the settings. A sub-sample of 48 responses that were coded by the second and

third authors was used to calculate inter-rater reliability (IRR). Agreement was calculated based on Cohen's kappa with values between 0.81 and 1.0 indicating near perfect agreement, 0.61 and 0.80 substantial agreement, and 0.41 and 0.60 moderate agreement [17]. Kappa values were determined for each of the themes. Themes, sub-topics, and IRR are summarized in Table 2.

Table 2. Role in Society Themes

Theme and sub-topics	Definition / examples	Kappa
Obligation		
Avoid harm Honesty Morality	"My role is to… further the advancement of ethical technology that contributes to the utility of earth and humanity without causing harm." "the duty to synthesize ethical designs"	0.878
Self		
Have good life	Make money or enjoy job	0.241
Important	"my role as a future engineer is very important."	
Societal benefits		
Advance humankind	"As an engineer, I am supposed to look for the betterment of humans whenever I can."	
Economic concerns	"My role as an engineer is to serve the customer in the most **efficient** and ethical way possible."	
Educate and inform	"entrusted with using our knowledge and abilities to protect humanity and **reveal possibilities** for our fellow people."	0.624
Improve quality of life	"help our society function more effectively"	
Joy/fun related	"To improve safety and **enjoyment of life**."	
Function/need related	"To develop new, more efficient, and more functional methods of accommodating the needs of society at large."	
Solve societal problems	"To solve issues in our infrastructure and societal well-being…"	
Public health		
Safety	"…keeping the safety of society is a paramount issue."	
Make world better place	"Make things better for society"	
Sustainability	Environmental and/or sustainability impacts	0.478
Technology	Develop technology and/or make technology useful to life; "Use my skills in math and design to make factories and machines more efficient."	0.643
Employer	"Complete the job I'm assigned/contracted to do"	0
Other / no impact	"functioning, but not highly impacting"	0.906

All of the themes except "self" and "employer" reached at least moderate agreement. Note that the themes were not discussed among the raters, which is a common practice to improve IRR. The kappa value for employer was low because one author coded it once in the sub-set and the other did not identify that theme in the sub-set. For the *self* theme, the raters differed in attributing statements about the importance of engineering to ***self*** importance. The sustainability theme also achieved only moderate IRR. One rater only assigned the sustainability code when students used the word *sustainability* in their response, while the other rater used a broader definition that included impacts on future generations.

For ethical issues survey question (RQ2), coding began by considering 18 ESI topics that were part of a faculty survey [18], shown in the 'theme' column in Table 3 denoted by a 1 superscript.

Table 3. Ethical issues themes

Theme	Definition and/or quote	Pre/ post n	IRR Kappa
Artificial intelligence (AI)	Self driving cars, machine intelligence	11 / 38	.638
Bioethics [1]	Modifying genetics, DAN, human and animal testing, cloning; often related to RCR	3 / 10	.790
Bribes	Bribery, money in exchange for influence	13 / 22	.658
Confidential / proprietary information	Corporate / company information that should not be divulged	7 / 13	.790
Conflict of interest	Deriving personal benefit from professional actions or decisions	8 / 22	.790
Diversity	Inclusivity, fairness (race, gender); may relate to SJ	7 / 8	.878
Economic issues	Costs, efficiency, money-related	77 / 85	.898
Employer / workplace - related issues	Responsibility to employer, profitability of company	30 / 54	.194*
Engineering and poverty [1]	Using engineering in developing countries, WASH (water, sanitation, health)	0 / 4	.790
Engineering decisions under uncertainty [1]	"lacking knowledge like the consequences of … fracking"	*2 / 10*	*.37*[+]
Environmental protection [1]	Natural resources, climate change, ecology	65/109	.73
Ethics in design [1]	Design issues	32 / 46	.634[*]
Honesty	Integrity, truthfulness	35 / 57	.634
Intellectual property (IP)	Patents, copyrights, trademarks; related to plagiarism	11 / 7	.79
Legal compliance	Obey laws, codes, standards, regulations	7 / 19	.73
Nanotechnology [1]	Explicitly says nanotech	1 / 6	.658[+]
Plagiarism	Taking credit for others work; related to IP but largely in educational setting	10 / 3	1.0
Privacy and civil liberties [1]	Personal data, net neutrality	9 / 28	.898
Responsible conduct of research (RCR) [1]	Research, experiments, data	24 / 19	.634[*]
Risk and liability [1]	Potential risks of technology	14 / 21	.468[*]
Safety [1]	Safety and/or health of people, public, workers	81/124	.747
Social justice [1]	Equitable distribution of wealth, opportunities, privileges; related to diversity or poverty	24 / 44	.39[*]
Societal impact	Impact on society, responsibility to public, advancing humankind	35 / 72	.819
Sustainability [1]	Further and/or long-term impacts on environment, society, and economy	30 / 64	.806[*]
War/military [1]	Technology for war or associated with military	5 / 8	1.0
Whistle blowing	Exposing activity that is unethical / illegal	4 / 1	1.0[+]
Other	'good', 'all', 'laziness', 'being a good person'	32 / 43	.444
NA / I don't know	IDK, NA, 'not sure what is being asked'	4 / 2	
None	"I don't think there are any."	0 / 1	

[1] among 18 a priori codes based on faculty survey; [+] 1 or fewer instances in random 50 sample; * IRR after second round of coding

The majority of those were macroethical issues, with microethics grouped primarily under 'engineering codes of ethics' and 'professional practice issues'. For the purposes of the coding, we broke the microethics down into areas such as bribes, confidential information, and legal compliance. Emergent themes were added to the codebook (e.g. honesty). Once the second author had coded the set of student responses, a random sub-set of 50 responses were selected and coded by the first author using the codebook. Inter-rater reliability was calculated based on Cohen's kappa. Ethical issues topics, definitions, and IRR are summarized in Table 3. For the codes with kappa values less than 0.60 (* in Table 3), the two coders discussed these codes with the fourth author. Subsequently, the first coder recoded all responses for the themes with low agreement, a new set of 50 responses were selected (with some intentional sampling of the low frequency codes) and coded by the second coder. Table 3 reports IRR from the second round for these themes.

After the second round of coding, all of the codes reached at least moderate levels of agreement, with the exception of engineering decisions under uncertainty (very rare in the sub-set with two coders) and employer / workplace issues. The main coder used the workplace code much less frequently than the second coder. The counts therefore are a very conservative estimate of the extent that student responses included workplace / employer issues.

To determine if there were statistically significant differences among the percentage of students who included a theme in their pre versus post responses, Fisher's exact tests were used; when the two tailed P value was 0.10 or less a significant difference was inferred. These tests are similar to chi tests but are better for low numbers of respondents. The quantitative comparisons among settings were limited by the small classes and low response rates. In addition, a rough comparison was conducted exploring potential correlations between students response on the Likert-type items on the survey (described above) and the total number of different ethical themes that were described in their open-ended response (IBM SPSS v. 25, Spearman's rho non-parametric test on strength of association; appropriate given the non-normal distribution of the data and ordinal response scale).

Results

The students' write-in responses to the role in society and ethical issues questions were a median of 16 and 11 words, respectively (maximum 137 to 100, respectively). The brevity of the responses likely reflects to some extent the level of care of the students, either due to their opinions on the importance of ESI topics, their enthusiasm for participating in a survey (versus care they would give a graded assignment), and/or lack of opinion and/or knowledge. Alternatively, engineering students may generally provide short answers to open-ended survey questions; in a study on writing with a survey given in mechanical capstone design, the responses ranged from 5 to 35 words with a median of 18 [19].

RQ1. Role in Society

The percentage of students whose responses to their role in society mapped to the six main theme areas are summarized in Table 4, sorted from the most to least common themes. The settings

where the largest and smallest percentages of students provided an answer related to the theme on the post-survey is also shown.

The most common theme among both the pre and post surveys was societal benefits. Among the eight settings where students completed the pre-survey, 78-100% of the students in each setting identified societal impacts among their roles in society. On the post survey, 50-93% of the students in each setting discussed societal impacts among their roles. In two settings, the percentage of students discussing societal benefits decreased more than 15% from the pre-survey, but the change was only statistically significant among students in the full ethics course at the religiously-affiliated institution. One reason for the decrease may have been that after the courses with significant ethics and/or 'professional issues' focus, the students transitioned from discussing their role in vague terms (e.g. 'make the world a better place') to more explicit statements that mapped to other themes.

Table 4. Themes in student responses to role in society question

Theme	Pre[8] % *n=269*	Post % *n=368*	Most Common settings and % on post surveys	Least Common settings and % on post surveys
Societal impacts	84	77	SrDsn-Env 93; Sust-Elect 89	Eth-Rel 50
Technology	30	29	EthPrf-Rel 63; Eth-Rel 43	Risk-Elect, SrDsn-Env, EWB 13
Obligation	17	20	Eth-Rel 72; Comm-Elect 31	EWB, EngSci-Req, Risk-Elect 0
Sustainability	17	20	FY-Civil 44; Eth-Rel 43	Comm-Elect, Eth-Een, EthPrf-Rel, Prf-All 0
Self	13	12	Sci-Elect & Sust-Elect 32	Eth-Rel & SrDsn-Env 0
Employer	9	4	Risk-Elect 25, EthPrf-Rel 13	6 @ 0 (Eth-Rel, Prf-Sr, etc.)

[8] Pre survey percentages represent only 8 instructional settings

Within the societal benefits category, a number of sub-themes were coded (Table 5). Many of these are quite similar, and reflect to some extent the word choice of the students. The most common theme on both the pre and post surveys was improving quality or way of life (across settings pre-survey 12-71%, post-survey 9-62%). The second most common theme on the pre-survey was solving societal problems (range across settings 8-40% pre, 0-30% post). The highest frequency of this theme was among first-year students at the religiously-affiliated institution; this perhaps aligns with public messaging that engineers solve problems and help society [2].

Table 5. Societal impact sub-themes

Theme	Pre[8]%	Post %	Most common setting, % on survey
Improve quality or way of life	34	32	EngSci-Req 62% post
Solve societal problems	24	16	FY-Rel 40% pre
Safety	15	16	SrDsn-Env 40% post, 36% pre
Advance humankind	11	15	EthPrf-Rel 43% pre
Part of society	11	11	Risk-Elect 25% post, SrDsn-Env 24% pre
Make world a better place	10	19	Prof-All 27% post, EWB 26% post
Educate	7	7	Sust-Elect 32% post; Prf-Sr-Priv 27% post
Public health	7	5	Prf-Sr-Civ & SrDsn-Env 16% pre
Function / need related	5	6	PrfEth-Rel 38% post
Economy	3	3	Sust-Elect 21% post

[8] Pre survey percentages represent only 8 instructional settings

The second common theme area in student responses related to technology development and/or making technology useful to life. This ranged from 0-42% of the students in each setting on the pre-survey, to 13-60% of the students on the post survey. In the professional issues course at the religiously-affiliated Master's institution, the percentage of student responses discussing this idea increased from 29% to 63%, but the difference was not statistically significant (p=.1975) likely due to the low number of students who participated in the post survey.

Types of obligations (e.g. honesty) were the next most frequently discussed; however, this differed quite a lot across settings. On the pre-survey, three settings had 20-28% of the students discuss obligations (FY-Civil, Prf-Sr-Civ, Ethics-Rel) while in four other settings 6% or fewer of the students talked about obligations. Among students taking an ethics-focused course at a religiously-affiliated institution, the percentage of students discussing obligations increased from high (28%) to very high (72%). The majority of these themes on the post-survey related to morality. The percentage of students discussing obligations also increased in a professional issues seminar course (from 5% to 27% Prf-All, p=0.097). In a senior-level civil engineering professional issues course, the percentage of students whose responses included obligation themes decreased significantly from 27% on the pre-survey to 7% on the post-survey (p=0.012).

Sustainability and/or environmental protection issues were discussed by 17% of the students on the pre and 20% on the post-survey (range among settings 0-44% on pre, 0-44% on post). In the full course on ethics at the large religious institution, the percentage of students discussing sustainability issues increased from 20% on the pre survey to 43% on the post survey (among 60-64 students). The 15% increase among first-year civil engineering students from 29% to 44% was not statistically significant (p=.226); the first-year seminar course included sustainability issues among the learning objectives. Among environmental engineering students in a capstone design course the percentage decreased from 44% to 27%, but the result was not statistically significant (p=.329) perhaps due to the somewhat low number of student responses on the post-survey. The initially somewhat high percentage is congruent with the environmental engineering discipline. It is somewhat surprising that the percentage was not higher on the post-survey in the sustainability-focused elective course (21%).

Response themes related to one-self were only identified among 13% of the students on the pre and 12% on the post-surveys (range among settings 0-27% pre, 0-32% post). In the full ethics course at the large religiously affiliated institution, the percentage of students discussing personal-related themes decreased on the post-survey from 27% to 0%. The self-related themes on the pre-survey among these students were primarily related to 'trying to be important' (n=13), and 'as a scientist / engineer' (n=6), a single student discussed personal curiosity and one discussed having a good life.

An emergent theme that was not discussed in the Canary et al. paper [14] but was found in some of the student responses in this study were responsibilities to one's employer. Although the theme was uncommon overall (9% pre and 4% post), it was more common in a few settings. For example, on the pre-survey 18% of senior civil engineers in the professional issues course and 13% of the students taking the full ethics course at the large religiously-affiliated institution included employer-related responsibilities in their responses. This decreased on the post-survey

to 7% and 0%, respectively (p .1273 and .006, respectively). The most common setting was among a small number of primarily upper-division students taking a cost-risks course (25% among 8 students on post survey; no pre-survey administered). It may be that the senior students have had internship experiences that shaped their perceptions, or are thinking more about the job setting after graduation.

A few students misinterpreted the question, and wrote an answer like "engineer" or "good". This implies that they don't normally think about what role in society they will play beyond the occupation of being an engineer. Some student responses were observed to focus on their current role as students; to avoid this, future surveys should perhaps be modified to state "how do you view your **future** role in society as an engineer or computer scientist."

RQ2. Ethical Issues

On the pre-surveys (n=225), a median of two different ethical issues topic themes were identified (range 1 to 6); two settings had median of three themes (Ethics-Rel and EWB). Across the 380 write-in answers on the post-survey, the median number of themes coded per response was again two with a range of one to seven. The median of two was consistent across all settings with the exception of 1.5 in Comm-Elect, 2.5 at Eth-Rel and FY-Civil, and 3 among EWB, Prf-All, and Eth-Prf-Rel. Thus, despite ethics content in all of the courses, students did not generally appear to increase the number of readily identifiable ethical issues they believed were relevant. Perhaps given the survey format students did not share the full-range of ideas they might have if the prompt had been part of a graded assignment rather than a survey.

When the total number of themes identified per student on the post survey were compared to the Likert-type response items, two weak correlations were found: student ratings of importance of ethical issues to engineering (Spearman's rho 0.184, two-tailed sig. 0.002) and average self-efficacy (preparation/ confidence across 4 items; Spearman's rho 0.140, two-tailed sig. 0.017). However, there were not correlations with students' rating of the importance of the consideration of societal issues to engineering (Spearman's rho .083, sig. .156) or the level they felt prepared to face ethical issues in their future work (Spearman's rho 0.90, two-tailed sig. 0.125). It was expected that if students' believed ethics was important they would have developed more knowledge of ethics and therefore greater feelings of preparation, as well as being able to list more ethical issues in their open-ended response. This expectation was only weakly supported by the data.

The ethical issues most commonly included by students across all of the settings are summarized in Table 6. Only the ethical issues that were fairly common among the write-in responses either overall (>15%) or in a particular educational setting (>15% or $n \geq 4$) will be discussed. Also, in one of the seven settings with pre-surveys, only three individuals completed the pre-survey; thus pre/post comparisons are limited to six settings.

Safety and human health issues were the most common theme included in the student responses on both the pre and post-surveys. This is a critical issue and the "paramountcy" requirement in most engineering codes of ethics. Comparing the pre and post-surveys, among students in a professional issues course (all ranks, all engineering majors) a much higher percentage included

safety issues on the post-survey than the pre-survey (64% vs. 33%). In contrast, fewer senior environmental engineering students in capstone design discussed safety issues on the post-survey compared to the pre-survey (33% vs. 52%); the decrease in students discussing safety was offset by a 16% increase in students discussing workplace related issues. The two settings where a low percentage of students discussed safety on the post-survey (13-16%) were both classes with a high percentage of non-engineering students, a communications course and an ethics course open to all majors. In addition, safety was not commonly discussed on the pre-survey by first-year students attending a religiously-affiliated institution (17%).

Table 6. Ethical issues identified by students

Theme	Pre[7] %	Post %	Most Common setting (% post survey)	Least common setting (% post survey)
Safety [1]	36	33	Prf-All (64), Risk-Elect (63)	Comm-Elect (13)
Environmental protection [1]	29	29	Sust-Elect (53), EWB (43), EngSci-Req (43)	Prf-All (9), Eth-Gen (12)
Economic issues	34	22	Prf-Sr-Cv (41), SrDsn-Env (40)	Eth-Gen (4)
Societal impact	15	19	Risk-Elect (50)	Prf-Sr-Priv (0)
Sustainability [1]	13	17	FY-Civil (28); EWB (26)	Comm, Risk, Prf-All (0)
Honesty	16	15	SrDsn-Env (33), FY-Rel (29)	Risk-Elect (0)
Workplace / employer issues	13	14	EthPrf-Rel (33), FY-Rel (26)	Prf-All (0)
Ethics in design [1]	14	12	Comm-Elect (38), Prf-All (36)	Risk-Elect (0)
Social justice [1]	11	12	EWB (35)	Sust-Elect, Risk-Elect, Prf-All, FY-Rel (0)
Responsible conduct of research [1]	11	5	Sust-Elect (16)	5 settings (0)
Artificial intelligence	5	10	Eth-Rel (33), Prf-All (27)	7 settings (0)
Risk and liability [1]	6	6	Eth-Gen (16), Risk-Elect (13)	7 settings (0)
Bribes	6	6	Prf-Sr-Civ (18), Risk-Elect (13)	6 settings (0)
Privacy and civil liberties [1]	4	7	Eth-Gen (32), Prf-Sr-Priv (19)	5 settings (0)
Conflict of interest	4	6	FY-Rel (24), Eth-Rel (15)	9 settings (0)
Legal compliance	3	5	EWB (17), Sust-Elect (16)	7 settings (0)
Intellectual property IP	5	2	SrDsn-Env (7)	10 settings (0)
Confidential / proprietary info	3	3	FY-Rel (9), Prf-Sll (9)	5 settings (0)
Diversity	3	2	Comm-Elect (13)	10 settings (0)
Plagiarism	4	1	Eth-Gen (8)	13 settings (0)
War / military	2	2	Prf-All (9), Eth-Rel (7)	10 settings (0)
Eng decisions uncertainty	1	3	EthPrf-Rel (11), EWB (9)	8 settings (0)
Bioethics	1	3	Sust-Elect (16), Eth-Gen (8)	9 settings (0)
Nanotechnology	.4	2	EngSci (10), Eth-gen (8)	11 settings (0)
Poverty	0	1	Prf-Sr-priv (6), EngSci (5)	11 settings (0)

[7] Only 7 settings had pre-surveys, while all 15 had post-surveys

Environmental protection was the second most frequently cited issue on the post-survey and third most common on the pre-survey. Environmental issues were more commonly discussed on the post-survey versus pre-survey by students taking an ethics/professionalism course at a

religiously-affiliated institution (33% vs 19%); less commonly discussed by first-year students at a religiously-affiliated institution (18% vs 30%). The current generation is being raised with environmental issues, particularly related to climate change, consistently in the news, which perhaps accounts for the somewhat high percentage of first-year students discussing this issue on the pre-survey. After learning more about engineering and technical aspects, their attention focused on other issues (e.g. conflict of interest increased 21%, workplace issues 20%). In five settings, fewer than 20% of the students on the post-survey discussed environmental issues, surprisingly including environmental engineering seniors in capstone design (13%). This contrasts with over half of students participating in an elective course on sustainability.

Economic issues were the third most common theme in student responses on the post-survey and second most common on the pre-survey. Students were often contrasting other issues against saving money, such as human health/safety or protecting the environment. The percentage of students discussing economic issues decreased 27% from the pre to post-survey in two settings, a full-course on ethics at a religiously-affiliated institution and an ethics/professionalism course at a religiously-affiliated institution. Two classes with seniors in civil/environmental engineering had the highest percentage of students discussing economic issues (40-41%), indicating that these students are aware of monetary-pressures or trade-offs against other issues (e.g. safety, environmental protection). In contrast, only 4 to 6% of the students in courses with many non-engineers discussed economic issues (communication and general ethics course), as well as 6% of the students in a senior-level professional issues course at a private military-focused institution.

Societal impacts in a general way were discussed by similar percentages of the students on both the pre and post-surveys (15% and 19%), and changes between pre/post surveys within a single setting were all less than 10%. It is notable that a much higher percentage of students discussed societal issues in response to the role in society survey question (77-84%). This difference may reflect that students are not taught to associate societal impacts with ethics, perhaps due to a primarily microethics focus or ‘code of ethics’ approach central to how undergraduate students are taught about ethics. The societal impacts topic had one of the largest differences among settings on the post survey, ranging from a high of 50% among students in a cost/risk elective course to 0% among seniors in a professional issues course at the private military-focused institution.

In only a few additional cases were there large changes in the percentage of students discussing a theme across the term on pre/post surveys. Among seniors in the ethics/professionalism focused course at a religiously-affiliated institution, 30% fewer students discussed honesty in their response. This may reflect shifting from somewhat general or broad ideas they would learn in liberal-arts focused ethics courses to workplace issues (increased 24%). Among first-year engineering students in an introductory engineering course at a religious-affiliated institution, 25% more students discussed honesty and 21% more discussed conflict of interest as ethical issues on the post survey, while 19% fewer discussed sustainability. The fact that more topics changed among first-year students likely reflects the fact that more advanced students in other courses have more developed ideas on ethics that are more resistant to change over the course of a single term.

Ten of the ethics topics had differences of 30% of more among the setting with the highest and lowest percentage of students discussing the theme on the post-survey: safety (51%), societal issues (50%), environmental protection (44%), ethics in design (38%), economic issues (37%), social justice (35%), workplace issues (33%), artificial intelligence (33%), honesty (33%), privacy and civil liberties (32%). Two more topics differed by 20-30%: sustainability (28%) and conflict of interest (24%). These differences among settings are likely the result of an array of factors including student majors, ranks, institutional settings, etc. Further research is needed to distinguish these effects.

Implications and Limitations

A primary limitation in the study was the low number and/or percentage of responses in some settings, and the lack of pre-surveys in half of the settings. This limited our ability to conclusively find differences across a term between the pre/post surveys and across settings. It is uncertain whether differences across settings that were widely found on the post-surveys were due to course content (given a lack of pre-surveys in half of the settings) or the overall curricular impact (differing by discipline and/or institutions).

Instructors may want to use these open-ended questions in a pre- and post- format. This will give them a sense of students' beliefs at the beginning of the course, and may indicate where to devote their attention during class. For example, if a large majority of the students' already discuss safety and the environment, instructors can devote more time during class with case studies and/or discussion of other issues. Changes on the post-survey could reveal which among the topics covered in class had the greatest impact on students. However, given the brevity of many students' responses, instructors may want to award credit and/or provide some indication that quality responses are desired. Alternatively, the question on ethics topics could be restated to encourage students to list a minimum number of topics (such as five) to get students to devote a little more attention to their response and perhaps stretch to think of issues. The type of responses could reveal if students associate ethics with more microethical issues (e.g. bribery, conflict of interest) or more macroethical issues (e.g. environmental protection, sustainability, social justice).

More broadly, programs may wish to use these assessment questions across the curriculum. Use in a pre-survey at the beginning of first-year could be complemented with intermediate surveys in sophomore or junior year, and culminate with a question a on survey for graduating seniors. This may reveal whether some elements are short-term artifacts of a particular course (such as particular topics listed in the post-survey) compared to more pervasive ideas that stick with students and reflect their ideas when they graduate from college and enter the workforce. The results could also reveal whether some co-curricular activities are particularly impactful, such as internships (perhaps increasing the percentage of students talking about employer-related issues in their 'role in society') or service activities (e.g. Engineers Without Borders).

Conclusions

A high percentage of the students described societal impact issues as they considered their future role as engineers / computer scientists (77-84%), about a third discussed technology in their

responses, and about one fifth focused on obligations or the environment/sustainability. However, student responses describing their views of their future role in society as practicing engineers or computer scientists generally did not reflect deep thinking. This was true despite deploying the survey in courses where ESI was a significant topic. This result may derive from multiple factors, including engineering students' reluctance to spend time writing on a survey, lack of practice reflecting on ESI, and a culture of disengagement in engineering.

When listing ethical issues they believed were relevant to engineers and/or computer scientists, the majority of the students again did not provide very extensive answers, listing only a median of two topics. The most common topics were those found in engineering codes of ethics, including safety (33%) and environmental protection (29%). Among the six settings where pre/post surveys were compared across 26 themes, only 8 of 156 comparisons differed by 20% or more. However, among the 15 settings there were 12 ethics topics that differed by 20% or more on the post-survey. Thus, the cumulative effects of disciplinary differences within engineering, institutional differences, and overall curriculum are likely more significant than the impact across a single term within a single course with ESI content. Weak correlations were found between the number of different types of ethical issues discussed and the Likert-type items on the survey related to the importance of ethics in engineering and feeling confident in analyzing ethical issues, which indicates the value in combining open and multi-response items for assessment.

Further research is needed to explore the ESI knowledge and attitudes of engineering students. This complex issue requires thoughtful methodology beyond what can likely be realized through short surveys. A combination of quantitative and qualitative items may provide richer information [19]. Knowledge and cognitive elements are likely easier to assess, in comparison to affective and attitudinal issues. However, one's personal feelings about ESI are particularly important, given that engineering practice frequently concerns societal impacts that should be considered in nuanced ways beyond mere legal compliance or simple rule-driven behavior (e.g. complying with codes of ethics). Graded assignments are also likely to elicit richer and more thoughtfully considered responses, while hopefully still providing genuine insight into students' views of ESI. The research findings may also indicate that engineering students should be asked to reflect on their thoughts around ESI more frequently in the course of their curriculum and training to become future professionals.

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