Incorporation of Ethics and Societal Impact Issues into First-Year Engineering Course:: Results of a National Survey

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Abstract

This paper summarizes the results of a national study that asked engineering and computing faculty to report the types of courses where they incorporated ethics and/or societal impact topics. An online survey was conducted in spring 2016, with 1216 responses from individuals who taught ethical and/or societal related topics in one or more courses. Among those who reported teaching ethics/societal impact issues in a course, 410 (34%) indicated that these topics were included in a first-year introductory course and/or first year design-focused course. Among 814 individuals who did not teach these topics in first year courses, 43% (n=350) believed that these topics were incorporated into first year courses in their program (35% into first year introductory course, 15% into first year design course). Among individuals who incorporated ethical/societal impact issues into first year courses, the most common topics were: professional practice issues, societal impacts of technology, engineering codes of ethics, safety, engineering decisions under uncertainty, ethical failures/disasters, and sustainability. The teaching and assessment methods used in first-year courses were described for 143 introductory courses and 56 design courses. The most common methods used to teach students about ethics/societal issues in these courses were: case studies, in class discussions, lectures, and examples of professional scenarios. Design courses also commonly included design and project based learning as methods to teach ethics. Common assessment methods for ethics/societal impacts learning were: individual reflective essays, test/quiz questions, individual homework, and group written assignments. Ten percent of the introductory courses and 9% of the first-year design courses did not assess ethics/societal impact learning outcomes. Reported satisfaction with the ability to assess ethics and societal impact learning outcomes averaged 4.5 (just over neutral to somewhat satisfied), and correlated with the number of assessment methods used. Five interviews were conducted with first year course instructors, and provided additional details. The results provide good examples of incorporating ethics and societal impact issues into courses for first year engineering students.

Introduction

It is important that all engineering and computing students develop an understanding of ethical issues and associated expectations for their discipline prior to graduation.[1] This is a requirement for program accreditation.[2,3] As well, ethical development is a key component of a liberal education.[4] Finelli et al.[5] characterize ethical development as inclusive of three elements: ethical knowledge, ethical reasoning, and ethical behavior. Ethical behavior is a critical expectation for those working as engineers and computer scientists, due to the enormous impacts of technology on human health and wellbeing, as well as the overall environment.

Professional ethics in engineering education and practice is a broad topic that can include a variety of issues. One approach is to classify these issues into microethics and macroethics.[6] Microethics includes an individual's responsibilities, including to their employer and profession. Microethics are a large focus of the engineering codes of ethics from professional societies.[7-12] Macroethics encompass the broader responsibilities of the profession to society, and are

associated with the societal and environmental impacts of technology. This can include issues such as sustainability, social justice, privacy, and poverty alleviation.

There are numerous reports in the literature of the infusion of ethical issues into first-year (FY) engineering courses. Finelli et al.[5] found that 84% of 3914 student survey respondents from 19 institutions noted learning about ethics in an introductory engineering course, experiencing an average of 4.8 different pedagogies in these courses. In a recent effort to create a taxonomy and mapping for first-year engineering courses,[13] eight main outcomes were characterized. Within these eight, four contained elements related to ethics. The taxonomy was applied to 28 first-year courses from 24 different institutions, as part of a workshop. Within the professional skills outcome, 20 of the 28 courses included 'ethics codes and standards'. Within the global interest outcome, sub-topics included concerns for society (11 courses), design safety (4 courses), and sustainability (added to taxonomy after data collected on the courses). With the engineering profession outcome, sub-elements related to macroethics include 'roles and responsibilities' (14 courses) and 'relevance of the profession' (19 courses). Finally, under the academic success outcome, academic integrity relates to the ethical behavior of students (21courses). Thus, a large number of different ethics-related topics were found in many different first-year courses.

There are a number of specific examples of first year courses focused on ethical issues. Clarkson University created a new 3-credit Engineering and Society course that includes a team design project, and an emphasis on ethics (assessed via homework and exams) and environmental, social, and sustainability considerations (assessed via homework, discussion, and exams).[14] Teaching methods for engineering ethics and society included role plays, case studies, discussions, and lecture, with a focus on active learning.[14] Assessment data from rubrics used to grade exam questions showed generally good fulfillment of ethics and societal context outcomes. In the first-year engineering seminar course at Bucknell University, the fourth and final segment focused on ethics and professional responsibility, including discussions of books focused on engineering and society.[15] In the FY introductory course at Elizabethtown College, small groups of students created fictional case studies that were written as short stories, films, etc. and were graded with a rubric.[16] These examples are not exhaustive but merely serve to highlight different teaching approaches used in FY courses.

A number of first year design-focused courses highlighting ethics and/or various macroethical issues have been reported, including courses at Arizona State University,[17] Pennsylvania State University,[18] and Rose-Hulman Institute of Technology.[19] Ethics and social impacts are key elements in projects with Engineers Without Borders at McMaster University.[20] Sustainability has been infused into FY design courses at Michigan Technological University,[21] Northeastern University,[22] and James Madison University.[23]

This initial education in engineering ethics sets an important foundation for the expectations of ethical behavior in engineers. However, the literature does not present a full picture of the extent to which engineering ethics instruction in the first-year is common. An understanding of the breadth of ethical issues addressed in first-year courses, how they are taught, and how learning is assessed is also lacking. These questions were explored in this research study.

Research Questions

Four questions were explored in this research:
RQ1. What topics related to ethics and societal impact issues are taught by instructors of first-year engineering courses?
RQ2. What methods are used to teach students about ethics and societal impact issues in first-year engineering courses?
RQ3. What methods are used to assess student learning of ethics and societal impact issues in first-year engineering courses?
RQ4. To what extent do faculty believe that engineering students learn about ethics and/or societal impact issues in first-year engineering courses?

Methods

Surveys. Through a process that included a literature review, surveys piloted at three institutions, and faculty interviews, two surveys were developed. Both surveys probed where and how faculty teach engineering and computing students about ethics and societal impact issues. Both surveys began with an informed consent statement that was approved for human subjects research by the Institutional Review Board at the University of Colorado Boulder (Protocol #15-0326). One survey started with questions on teaching in courses, and was distributed to engineering ethics instructors and researchers via targeted emails and list serves. The second survey started with questions on teaching in co-curricular environments, followed by questions on courses. The survey was distributed to mentors of co-curricular activities. More details on the survey development and distribution has been published.[24-26] Individuals who taught first-year courses were not directly targeted to participate in the study. In both surveys the questions on course-based instruction were identical. Both surveys concluded with the same series of demographic questions (institution, rank, gender, etc.).

Respondents. Overall, 1448 responses were received, although some were partially complete, including lacking demographic information. The respondents represented 419 different institutions. Institutional affiliations of the respondents included 48 from religiously affiliated institutions, 20 individuals from Hispanic serving institutions and 2 from HBCUs. A sub-set of respondents (n=410) indicated that they taught ethics and/or societal impact issues in first-year engineering courses; 195 of these individuals describe one or two FY courses in detail. The demographics of these respondents are summarized in Table 1, and compared to the pool of other survey respondents. Note that FY courses were less common than sophomore/junior engineering science/engineering courses (n=477) and senior capstone design (n=475) as a course type where respondents indicated they infused ethical/social issues. Respondents represented all faculty ranks; those who described FY engineering courses were somewhat over-represented in the instructor rank compared to respondents who did not include ethical/social issues in FY courses. The respondents taught a wide range of engineering and computing disciplines. Females were over-represented among the individuals who reported teaching ethical/social issues in FY courses, compared to the percentage of females teaching these topics in non-FY courses and among T/TT faculty in engineering.

Table 1. Demographic Characteristics of Survey Respondents

Characteristics	Described FY course, % (n=194)	FY course instructors, % (n=410)	Other respondents, % (n=1014)	National ASEE statistics[27]
Institutions	(140 diff)	(244 diff)		
Public	67	68	74	
Private	33	32	26	
Doctoral	65	68	85	
Master's	20	18	10	
Bachelor's	13	12	5	
Ranks				
Full professor	26	32	35	40
Associate professor	27	29	27	23
Assistant professor	18	15	18	19
Instructors	20	15	9	12
Other: part time, adjunct, staff	8	9	11	7+
Other institutional roles				
ABET assessment coordinator	10	10	8	
Director of program or center	15	16	15	
Department head or chair	10	11	7	
Other roles		11		
Disciplines taught (can be multiple)	(n=192)	(n=408)	(n=984)	
First year engineering	48	35	3	N/A
Civil engineering	25	22	19	12
Mechanical engineering	23	21	21	17
Computer science/engineering	13	16	18	13
Electrical engineering	14	14	12	21
Chemical engineering	11	12	9	7
Environmental engineering	10	11	12	4
General engineering	9	9	4	2
Biomedical	8	9	10	6
Materials	6	4	5	4
Industrial	5	5	7	4
Aerospace	5	4	5	3
Others (eng tech, nuclear, etc.)				
Male	53	60	67	
Female	44	38	30	15.5*
Prefer not to say	3	2	3	

Respondents could skip questions, so some demographics represent fewer respondents
* Tenured/tenure-track; + full-time equivalent of all part-time personnel

Data Analysis. Statistically significant differences in the number of topics, number of courses, number of ethics teaching methods, etc. were evaluated using non-parametric tests in SPSS (either Mann-Whitney U Test when comparing two groups, or Kruskal-Wallis test for more than two groups). Statistically significant differences between teaching a particular topic or particular teaching method (yes/no) were determined using chi-squared tests. Open ended responses were

explored using emergent coding methods, establishment of a code book, and three raters coding a sub-set of the responses to establish inter-rater reliability; more details are available in Canney et al.[28]

Interviews. The interview phase of the study was designed to gain a deeper understanding of exemplary teaching practices and gain insight into educators' perceptions of their efficacy. At the end of the survey, respondents were invited to provide their email address if they were interested in being contacted for a follow-up interview. Of the over 1400 total responses that were collected from the surveys, 229 respondents volunteered to be interviewed. Among this group, 39 had described a FY introductory and/or design focused course earlier in the survey. Individuals were invited to participate in interviews to represent a range of pedagogical approaches in different disciplinary, academic, and institutional settings. Instructors of FY courses were not intentionally invited nor excluded from selection for the interviews. Between October 2016 and April 2017, 52 individuals were invited to participate in interviews via email. As of April 13, 2017, 37 interviews were completed. Of the 37 educators interviewed, five discussed their first-year introductory courses and some of the interview data is included in this paper to provide additional richness to the results. The semi-structured interviews were conducted via Skype or phone and were 30-60 minutes in duration. Prior to the interview, participants were emailed a consent form for review and verbal consent was collected at the start of the interview. The interviews were recorded via Callnote. After the interviews, 2-page summaries were written and emailed to the interviewee for a member check to increase the accuracy and validity of the qualitative research.[29] The audio files were used to generate verbatim transcripts using Dragon Speak. Pseudonyms were assigned to the interviewees using a random name generator to protect the anonymity and confidentiality of the participants.[30] Complete analysis of the interview data is still in progress.

Results and Discussion

RQ1. Topics

The first survey question related to this study asked individuals to indicate the ethics topics that they taught in one or more of their courses (18 topics were identified, an additional "other" was provided with a space to write-in; "no topics" was also an option). For any individuals who selected one or more topics), this was followed by a question where respondents indicated all of the types of courses where they taught these topics (9 options provided and "other"); results are summarized in Table 2. Among the survey respondents, 71 only reported teaching these topics in first-year courses (either first-year introductory course and/or a first-year design course) and no other types of courses. On average, four different ethics related topics were reported by each instructor of these first-year courses. The most common topics integrated into the FY courses were: the engineering code of ethics, societal impacts of technology, professional practice issues, safety, and sustainability. Some of these topics are macroethical issues, although it is unclear the extent to which topics such as professional practice issues and sustainability are taught with a focus on ethics. Other topics written-in included: medicine and technology; human centered design; global diversity and perspectives.

Table 2. Percentage of instructors reporting teaching the topic in one or more courses

Ethics-related topics	Only FY courses (n=71)	FY Intro and others (n=365)	FY Design and others (n=153)	Non-FY courses (n=806)
Engineering Code of Ethics	56	61	62	42
Societal impacts of technology	45	64	70	53
Professional Practice Issues	45	67	69	59
Safety	39	55	68	47
Sustainability / sustainable development	37	54	62	44
Engineering decisions under uncertainty	34	54	64	49
Ethical failures / disasters	34	55	59	41
Ethics in design	28	48	59	41
Environmental protection issues	20	42	41	35
Responsible conduct of research	18	34	35	34
Social justice	15	24	25	17
Engineering and poverty	14	23	31	14
Risk and liability	14	40	41	36
Ethical theories	10	27	28	23
Other	6	6	6	11
Bioethics	4	10	10	8
Privacy and civil liberties	3	18	16	13
War, peace, military applications engrg	3	10	10	9
Nanotechnology	1	5	6	4
Average number of course types with ethics	*1.3*	*3.2*	*3.9*	*1.8*
Average number of ethics topics	*4.3*	*7.7*	*7.0*	*5.8*

For comparison, the topics taught by instructors who reported teaching FY courses in addition to other course types are shown (which included individuals at 244 different institutions and 8 anonymous responses), as well as topics taught by instructors of non-FY courses. Since these results represent a larger number of multiple types of courses, it isn't surprising that most of the topics were reported more frequently by those instructors compared to only FY instructors.

RQ2. Teaching Methods

Instructors were asked to describe up to two courses where they taught ethics/societal impact issues. This resulted in 140 individuals describing 143 first-year introductory courses and 55 individuals describing 56 FY design courses (1 individual described a FY intro and FY design course). The 194 individuals who described FY courses represented 140 different institutions (and 5 anonymous responses). Among the FY introductory courses, 87% were required for students in one or more engineering majors and 14% were electives for students in one or more engineering majors (1 course was listed as both). For the FY design courses, 89% were required and 13% were electives (1 course was listed as both). The majority of the FY introductory courses described appeared to be general in scope (based on titles, e.g. Introduction to Engineering, Foundations of Engineering, First Year Seminar), with 34% targeted to specific majors (such as aerospace, biomedical, civil, chemical, electrical, environmental, industrial, materials, mechanical engineering and computer science). Some courses were part of a sequence (e.g. Introduction to Engineering I, Fundamentals of Engineering II), others were seminar

courses. The majority of the FY design courses appeared general in scope, with only 18% clearly targeted to specific disciplines.

For their specific course, instructors were asked to indicate the methods they used in the course to teach students about ethics and/or societal issues; results are summarized in Table 3. On average, about five different methods were reportedly used to teach ethics/societal impact issues in FY courses. This is similar to the student survey results from Finelli et al.[5] where on average, about 5 pedagogies that were employed to teach ethics were experienced in first-year introductory courses, although upper division students recalled fewer pedagogies at 4.2. The most popular teaching methods identified in our study were: case studies, lectures, in-class discussions, and examples of professional scenarios. The FY design courses were much more likely to include design, PBL, and SL as compared to the FY introductory courses. The ethics education pedagogies in introductory engineering courses that were most commonly reported by students in the Finelli study were: presentation by professor (73%, similar to lecture), presentation by person speaking about own experiences (44%), and discussion with classmates (41%).

Table 3. Percentage of FY courses where ethical/societal issues were taught using a particular type of teaching method

Types of methods used to teach ethics/societal impact issues	FY intro courses (n=143)	FY design courses (n=56)
Average number pedagogies	*4.8*	*5.5*
Case studies	65	63
Lectures	65	59
In-class discussions	64	66
Examples professional scenarios	62	52
Guest lectures (e.g., philosophers, social scientists)	34	21
Design	32	61*
Videos, movie clips	29	29
Project based learning	27	66*
Reflections	24	36
In-class debates and/or role plays	18	20
Think-pair-share	13	21
Service-learning, community engagement, and/or LTS	10	29*
Problem solving heuristics	10	9
Humanist readings	10	7
Moral exemplars	8	5
Other(s) [fill in]	7	5

* compared to FY intro courses; chi-square significance <0.05

Other teaching methods that were written in included:

- research with write-up and/or presentation (individual and/or group; 3x)
- creative / fictional writing (3x)
- play a board game (2x; Dilemma, environmental ethics)
- field trips (2x)

- interviewing professionals
- user empathy exercises
- small group discussion with written questions, sort of an 'enlarged' think-pair-share
- inclusivity in communications
- development of public communications about engineering ethics.
- aspect of a small design project aimed to get them to think about the broader impacts of a civil engineering project
- readings of essays that explore biblical implications on engineering perspectives

In cases where topics and teaching methods could be linked, it appeared that some topics were perhaps more commonly taught via particular methods. For example, case studies were more common where the Code of Ethics and societal impacts of technology were being taught (69% and 71%) versus sustainability (45%); examples of professional scenarios appeared more commonly associated with the Code of Ethics (56%) than societal impacts of technology (48%) or sustainability (38%). Project based learning seemed more commonly associated with sustainability (46%) compared to the Code of Ethics (36%).

Beyond the conventional case studies, lectures, and discussions, FY introductory courses afford the opportunity to integrate creative assignments. Turning to the interview results, one interviewee, who teaches a two-credit FY course required for all engineering students, uses creative assignments to facilitate ethical awareness in his students. The students create and display a narrative about an ethical situation that they might realistically encounter in the next 5-10 years. The teams choose the characters, settings, and scenarios and have creative control over how the story is shared with the class. From making videos, acting out skits, recording readings, or illustrating graphic novels, students take time to develop stories and reflect on the ethical underpinnings with the class. The assignment provides a creative outlet for students while helping them connect ethics to their own lives. As the interviewee commented, “case studies in ethics are these big catastrophes that students will read and see they did the wrong thing but do not see how it will affect their decision next week” so the assignment is designed to bridge this gap and make ethics relatable and relevant. Students in the class also develop their own codes of ethics and map the rules of practice to their own lives to contextualize ethics in their own experience and understand the importance of ethical behavior.

According to the interviewee, FY introductory courses offer a valuable primer for ethics and broader impacts education with students thinking about the ethical and societal implications of engineering “ahead of time and being prepared for when they face” dilemmas in their academic and professional work. However, the survey format of the courses limits the time available for ethics and broader impacts instruction. Covering a broad sweep of topics, from software packages to electro-mechanics, leaves only a few sessions to discuss ethics and broader impacts whereas “we could really spend the whole course on this.” Due to the full curriculum in engineering education and tight scheduling, it is imperative to make the most of the time allotted and using a variety of teaching methods, including creative assignments, can cultivate student engagement and help students realize the importance of ethical behavior in their own lives.

Another interviewee, who teaches a required three-credit introduction to chemical engineering course, developed an activity to teach engineering ethics and societal impacts through history.

The students are tasked with researching the history of the discipline and developing a timeline of significant events and milestones. The groups present their findings to the class and compile a chronology of chemical engineering. The activity then opens a discussion of significant events, positive or negative, over the last century to demonstrate the impact of engineering on society. From learning about Chernobyl to the creation of the atomic bomb, students gain an awareness of the socio-technical interplay. By positioning the activity at the beginning of their coursework, the instructor facilitates an understanding of chemical engineering through a macroethical lens. The activity could be applied to any discipline and fits in a single class period making it a flexible and transferable opportunity to teach freshman and sophomore engineering students about ethics and societal impacts.

RQ3. Assessment Methods

Instructors of FY courses reported an average of about two methods were used to assess student learning related to ethical / societal impact topics (ranging from no assessment to eight different methods for a single course). The most commonly used assessment methods (Table 4) were: individual reflective essays, individual homework assignments graded with a rubric, and group-based written assignments. The differences in the assessment methods that were most prevalent in the two types of FY courses were not statistically significant. For example, test and/or quiz questions appear more commonly used in the FY introductory courses vs. FY design ($p = 0.10$).

Table 4. Percentage of courses that use different assessment methods for outcomes of ethics / societal impacts instruction

Types of methods used to assess ethics/societal impact issues	FY intro courses (n=143)	FY design courses (n=56)
Average number assessment methods	*2.1*	*2.4*
Individual reflective essays	44	46
Test and/or quiz questions	39	27
Individual homework assignment, essay, and/or papers that are graded with a rubric	36	48
Group-based written assignment	36	45
Individual homework assignments where questions have fairly straight forward right and wrong answers (similar to Fundamentals of Engineering type questions)	17	13
Surveys	15	14
Team ratings	13	21
Do not assess these learning outcomes	10	9
Other (describe)	8	14
Individual standardized assessment method (DIT, EERI, ESIT, etc.)	1	2

Other assessment methods that were written in include:

- presentations by the students (individual and/or group; ~10x)
- throughout the course on their decisions, and on the final solution
- individual homework assignments not graded with a rubric
- students develop a bibliography of peer-reviewed research

- students apply concepts and theories to contemporary issues
- individual project
- game-based quests
- students develop a case study
- professional practice minute grade
- have tested it by DIT2 in the past
- EPSA (Engineering Professional Skills Assessment)

Also, more information provided on some of the options, such as: "Exams are primarily take-home open-ended case studies with guided questions, so not quite a 'paper' but 2-3 pages of written response. Also a closed-book final exam with both "right/wrong" questions and open-ended discussion." Another comment relevant to exams was: "minimal assessment in exams." An example of more detail provided on the presentations is: "Team presentations include ethical considerations on rubric given to students thus it is a component of final project grade."

It is likely that different assessment methods are used to assess different ethical learning outcomes, based on topics, level of Bloom's taxonomy, ethical knowledge vs. reasoning, etc. Some evidence of this was found looking at the small number of individuals (n=66) who reported both topics and assessment methods. For example, test/quiz questions were associated with 44% of those who taught the Code of Ethics, compared to only 39% of societal impacts of technology and 35% of sustainability. Individual homework graded with a rubric seemed more common with sustainability (38%) and societal impacts of technology (39%) than Code of Ethics (31%). Future work is needed to explore this idea further.

Reported satisfaction with the ability to assess the outcomes of societal context and ethics instruction ranged from 1 to 7 on a Likert scale (Table 5), averaging 4.4 for FY introductory courses and 4.5 for FY design courses. For the FY introductory courses there was a trend that a higher level of satisfaction with assessment appeared correlated with the use of a larger number of assessment methods (Spearman's rho 0.340, 2-tailed sig. 0.000). This same relationship was found in the FY design courses (Spearman's rho 0.371, 2-tailed sig. 0.005). The averages in Table 5 roughly communicate this trend. The results imply that the use of multiple assessment methods for ethics/societal impacts instruction in FY courses results in a higher level of instructor satisfaction.

Table 5. Satisfaction with ability to assess ethical learning

Satisfaction with ability to assess	FY Introductory Courses		FY Design Courses	
	n	Avg # assessment methods	n	Avg # assessment methods
1 Very Dissatisfied	6	0.92	0	n/a
2 Dissatisfied	10	1.30	7	1
3 Somewhat Dissatisfied	20	1.85	4	1.75
4 Neutral	23	1.70	14	2.43
5 Somewhat Satisfied	52	2.38	16	2.81
6 Satisfied	22	2.59	10	2.40
7 Very satisfied	8	3.25	4	2.75

RQ4. Perceptions of Ethics Instruction in FY courses

A question on the survey asked instructors where they believed undergraduate students in their program learned about the societal impacts of technology and/or ethical issues. Among 814 respondents who indicated 1 or more courses and did not teach these topics in FY courses themselves, 43% believed students learned about these topics in FY courses; 35% in introductory courses and 15% in FY design courses (7% in both). These responses may reflect different majors and institutions than the FY instructors, but may also indicate a lack of awareness that these issues are frequently infused into FY courses. For example, at one large public institution among four civil engineering instructors, one taught ethical/social issues in a first-year course and that was also the only person who thought students learned about these topics in first-year courses. At a private institution among five mechanical engineering instructors, one taught ethical/social issues in a FY course but only two (include the FY instructor) believed students learned about these issues in a FY course. In contrast, at a technically-focused institution, two of four civil engineering instructors taught ethical/societal topics in FY courses, but all four were aware these topics were included.

There were 119 instructors of FY introductory and/or design courses who wrote in comments to the open-ended question at the end of the survey. A number of the open-ended comments indicated that first-year instructors felt that instruction on ethics and societal impact topics could be improved (n=24) and that these topics were very important (n=17). FY instructors also discussed the impacts of engineering on communities as an teaching strategy (n=12). For more analysis see Canney et al.[28] Examples of statements specific to FY courses also included concerns that not all faculty value ethics instruction or feel qualified to teach these subjects (n=8):

> "This is almost treated as an afterthought. In our department introductory course, it is considered to be essential but only constitutes one lecture and generally with a presentation by a faculty member from another department, implying that our faculty don't want to take the time."

Comments also reflected the importance of embedding ethics and broader impacts across the curriculum and not limiting student exposure to introductory and senior design courses. Responses that exemplify this theme include (n=15):

> "I think our undergrads are getting (barely) enough info on ethics through case studies and guest lectures during freshman seminar and senior capstone design courses, although more exposure would be better. They really don't get much about broader impacts unless they happen to be involved in an extra-curricular activity like EWB. Our graduate students get no formal exposure to either of these topics, unless we happen to have a speaker at our graduate seminar."

> "All engineering faculty should try to reinforce these concepts in their courses. It should not be the responsibility of only the environmental engineering or freshman course faculty."

> "At our institution, coverage of ethics and social responsibility is weakest in a number of programs (e.g., electrical and computer engineering) where it is mainly covered via required

first-year engineering courses, 0- or 1-credit professional seminars, and senior/capstone design courses. It is strongest in programs (e.g., biomedical engineering) which require multiple ethics courses, included required coursework in the discipline and additional electives focused on more specific topics."

Overall, the majority of comments from FY instructors appear to acknowledge the importance of teaching students about ethics, the significant role that FY courses play in the ethical instruction of engineering students, and advocate for reinforcement later in curricula.

Limitations

The first key limitation to consider is that individuals who responded to the survey were more likely to be involved in ethics education than typical instructors. Thus, one should not assume that ethics and/or societal impact issues are included in a majority of first year engineering courses. The perceptions of the non-FY instructors may be accurate in this regard. FY instructors were not directly invited to participate in the study, but were only included in general invitations to participate in the research study.

Second, the survey was a starting point to understand how ethics is taught and assessed in first-year engineering courses. However, more sophisticated information would be needed to establish the types of topics and levels of knowledge or reasoning that are outcomes from the instruction. At present, no distinction has been made between three credit versus one credit introductory courses of a quarter or semester duration, for example. It is also unclear if ethics is covered in a single lecture or homework assignment, versus more in-depth infusion into the course as a whole. Further, how the first-year course (either introductory and/or design) fits into the overall plan for ethical education in a curriculum is likely to vary significantly. Some of the instructor responses of where ethics is taught seemed to reflect an "ethics across the curriculum" approach, while others evidenced a more "bookend" philosophy or even a full course focused on engineering ethics but perhaps somewhat isolated in that single course. Future research should delve more deeply into these distinctions.

Future Work

At present, faculty are being interviewed to gain deeper insights into their ethics instructional methods. The goal is to identify course models that appear particularly effective, and then study them in more depth as case studies using observation methods as well as student and alumni feedback. This is important because what is taught and what students learn cannot be assumed to be the same. In addition, effective ethics instruction might not be fully appreciated until years later when someone encounters a particular situation in their engineering work. A survey targeted specifically to FY instructors might better determine the percentage of these FY courses that do and do not include particular topics and objectives around ethics instruction.

Conclusions

This exploratory study identified a large number of individuals (n=410) who indicated that they incorporated ethical and social issues into first-year engineering courses across a wide number of

institutions and a range of disciplines. These FY courses commonly included topics such as the engineering code of ethics, societal impacts of technology, and professional practice issues. Over half of the first year introductory (n=143) and FY design (n=56) courses taught ethical/social issues using case studies, lecture, in-class discussions, and examples of professional scenarios. Over half of the FY design courses also taught ethical/social issues via design and project-based learning. About 90% of the FY courses described by the respondents assessed the outcomes of students' education about ethical/social issues. Across about 45% of both introductory and design courses, reflective essays were used for this assessment. The FY design courses also commonly assessed ethics instruction via individual homework assignments graded with a rubric and group written assignments (likely the report accompanying the team design project). Assessing students ethical development can be challenging, but some of those using multiple methods were very satisfied with their ability to assess the outcomes of their teaching of ethical/social issues. The results indicate that ethical/social issues appear very compatible with typical FY engineering courses, and can be infused via a variety of teaching and assessment methods.

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