Effective Ethics Education: Examining Differing Faculty Perspectives

Dr. Angela R. Bielefeldt, University of Colorado, Boulder

Angela Bielefeldt is a professor at the University of Colorado Boulder in the Department of Civil, Environmental, and Architectural Engineering (CEAE). She had served as the ABET assessment coordinator for the department since 2008. Professor Bielefeldt is a licensed P.E. Her research interests in engineering education include service-learning, sustainable engineering, social responsibility, ethics, and diversity.

Ms. Madeline Polmear, University of Colorado, Boulder

Madeline Polmear is a PhD student in the Department of Civil, Environmental, and Architectural Engineering at the University of Colorado, Boulder.

Dr. Chris Swan, Tufts University

Chris Swan is an associate professor in the Civil and Environmental Engineering department at Tufts University. He has additional appointments in the Jonathan M. Tisch College of Citizenship and Public Service and Center for Engineering Education and Outreach at Tufts. His current engineering education research interests focus on learning through service-based projects and using an entrepreneurial mindset to further engineering education innovations. He also researches the development of reuse strategies for waste materials.

Dr. Daniel Knight, University of Colorado, Boulder

Daniel W. Knight is the Program Assessment and Research Associate at Design Center (DC) Colorado in CU's Department of Mechanical Engineering at the College of Engineering and Applied Science. He holds a B.A. in psychology from Louisiana State University, an M.S. degree in industrial/organizational psychology and a Ph.D. degree in education, both from the University of Tennessee. Dr. Knight's research interests are in the areas of retention, program evaluation and teamwork practices in engineering education. His current duties include assessment, team development and education research for DC Colorado's hands-on initiatives.

Dr. Nathan E. Canney,

Dr. Canney conducts research focused on engineering education, specifically the development of social responsibility in engineering students. Other areas of interest include ethics, service learning, and sustainability education. Dr. Canney received bachelors degrees in Civil Engineering and Mathematics from Seattle University, a masters in Civil Engineering from Stanford University with an emphasis on structural engineering, and a PhD in Civil Engineering from the University of Colorado Boulder. Dr. Canney taught in the Civil and Environmental Engineering Department at Seattle University for four years and now works in private consulting.

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Abstract

The question of what comprises effective engineering ethics education is intriguing and complex. Broadly, this research is attempting to identify strong models for macroethics education, so-called "exemplars". Faculty interviews resulted in 35 descriptions of current ethics instructional practices: two programs, 32 individual courses (including first-year, capstone design, required and elective technical courses, and standalone ethics courses), and one co-curricular setting. Based on tenets of the I-Corps-L™ program, particularly its "customer discovery" process, the goal of the interview analysis was to determine which of these teaching methods warranted further study as exemplars of macroethics instruction which have the potential be scaled and sustained at locations beyond their existing level of use. To assist in this process, four evaluation criteria were established: (a) likely to have a high impact on student learning; (b) strong assessment methods; (c) novel or innovative; (d) transferability (to other institutions or disciplines); these were rated on a scale from 1 (low) to 4 (high). An overall evaluation on level of interest / excitement for including this teaching example in further research employed a 1 (low) to 10 (highest) scale. Raters could also provide open comments. The interviewees were asked to rate at least six de-identified teaching examples, and 29 sets of ratings were completed. The five members of the research team each rated 19 to 35 teaching examples. This resulted in a minimum of eight ratings for each teaching example. These ratings often had wide disparities. For example, ten cases had ratings for novelty across the full spectrum from 1 to 4, demonstrating a lack of consensus. The write-in comments provided insights into differences in what raters perceived as novel, transferable, or likely to impact students' learning. Given the disparities in opinions, it would be useful to develop and implement a standard assessment method for ethics teaching modalities to better delineate what constitutes an exemplar.

Introduction

There have been a number of calls to improve the education of engineering students on ethics and societal impact issues (ESI), encompassing both microethics and macroethics [1-3]. One approach that might increase the amount and quality of ESI education in engineering is to identify and promote "exemplars". These models of ESI education can help current ethics educators to improve their teaching and/or assessment practices, as well as inspire others to integrate ESI education into their courses. This approach has been taken by the National Academy of Engineering (NAE) which recently published a compendium of 25 "exemplary education activities and programs" [4]. These were selected from among 44 submissions that "connected ethics to technical engineering content" and included assessment. A variety of selection criteria were considered, including demonstrated impact on students, potential for replication at other institutions, innovative approach, and use of active learning. In addition, the examples could be focused on microethics, macroethics, or both. The report also stated that they received comments from those who submitted their education activities that noted "a lack of consensus on important topics and methods for incorporating ethics in an already overstuffed curriculum (topical and pedagogical challenges)" [4, p. 2].

The key question is: What defines exemplary ESI education for engineering students? It is likely that different individuals would include diverse factors in this consideration, as well as weigh the relative importance of various factors differently. A few potentially impactful criteria are elaborated below.

Some would categorize particular ESI topics as imperative, while others may view these same topics as unnecessary. For example, the American Society of Civil Engineers (ASCE) includes sustainability ethics within its Civil Engineering Body of Knowledge [5] and promotes sustainable development within its Code of Ethics [6]. Some other engineering groups also include sustainability within their codes of ethics (e.g. NSPE, ASME, IEEE [7-9]), but other disciplines do not mention sustainability within their codes of ethics (e.g. AIAA, BMES, AIChE [10-12]). Some groups strongly promote ideas of social justice in engineering (e.g. Engineering Social Justice and Peace, EJSP [13]), but it is unclear that this is widely endorsed [14]. Ethical issues around diversity appear in the ethics codes of the ASCE [6], AIChE [12], and IEEE [9]. Thus, the ethical standards within engineering evolve over time, and appear to evolve differently within various sub-disciplines or organizations.

Another criterion for exemplary ESI education might include the cognitive, affective, and/or behavioral outcomes desired. This could be conceptualized from the framework of Bloom's taxonomy ranging from knowledge (lower level) to ethical reasoning (higher level) [6]. It could also be conceptualized around stages such as recognition of an ethical dilemma, gathering relevant information, analysis of information and correctly applying ethical constructs, considering the perspectives of multiple stakeholders, and selecting an optimal solution from among multiple options [15]. Alternatively, one can think about teaching students about ethics (knowledge), which has informative goals, versus teaching students to be ethical in practice, which has formative and transformative goals for behavior [16]. Engineering ethics educators appear to have quite different goals around these desired educational outcomes, as well as different perceptions of what is possible.

A model of exemplary education might also include something novel or innovative that is not currently widespread practice but has the potential to be impactful. For example, case studies have been a staple of engineering ethics education for a long while [17, 18], but less widely used approaches could prove more effective for particular types of ethical outcomes.

If the goal of ESI education is more ethical engineers in practice, then widespread use of impactful ethics teaching methods is imperative. This brings in the element of transferability to discussions of exemplary ethics education. For example, if the stories from the faculty of their own personal real-life ethical dilemmas from practice or the individual personality of the faculty member are critical to particularly effective ethics education, those attributes are difficult to transfer to other institutions. Some instructional strategies may be limited to particular topics, such as bioethics, that tend to be specific to certain disciplines. Thus, transferability must consider stylistic, disciplinary, and contextual factors [19].

An on-going research project initiated in 2015 has goals to promote quality macroethics education in engineering and computing. This effort began by developing a survey that was widely disseminated in spring 2016, resulting in 1448 respondents representing 418 institutions. The majority of respondents felt that the ESI education of both undergraduate and graduate students in their program was not sufficient [3]. Among the responses, there were many cases where engineering and computing educators from within the same program at the same institution did not agree on whether their students were receiving adequate education on ESI [20, 21]. In some cases, this was the result of differing perceptions of the types of courses where ESI was being taught to students – either based on incomplete information of the faculty and/or differing perceptions of what "counts" as ESI education. The open-ended responses provided evidence that faculty differ in their goals and aspirations toward ESI education. Two contrasting, divergent examples are: "I think both of these topics are overblown in engineering education. Students need to be aware of these but would be better served by improved technical education" versus "There is not enough focus on this. The advanced engineering skills needed for practical application can be learned on the job. The ethical and broader impacts on society are not typically taught on the job and if these are not taught at the undergraduate level, too many students will learn them only after making serious mistakes."

The next step in the research was to select potential exemplars of ethics education for further study. From among the survey respondents, 231 volunteered to participate in interviews on their ethics instruction practices. For these interviews, the research team wanted to select potential exemplars that cross an array of course settings, teaching methods, and disciplines. Then, based on the interviews, select a small number of ESI teaching settings to study in more depth. This process raised questions of how to identify exemplars, and to what extent individuals would agree or disagree in these determinations.

Research Questions

This paper explores the following research questions.

RQ1. Among examples of ESI teaching practices for engineering and computing students, do the teaching settings rated high for student <u>learning</u> potential correlate with strong <u>assessment</u> or <u>novelty</u>? How do these ratings compare overall?

RQ2. To what extent is there consensus or disagreement among the ratings of teaching settings for student learning, assessment, and novelty?

RQ3. Among examples of ESI teaching practices for engineering and computing students, to what extent are the ratings for different types of <u>transferability</u> correlated? To what extent do different raters agree in their ratings for transferability?

RQ4. Among examples of ESI teaching practices for engineering and computing students, which practices generated the most overall <u>interest</u> for more detailed exploration? To what extent is there consensus among the ratings?

RQ5. Are there differences by course type, engineering vs. non-engineering instructor, or engineering vs. non-engineering rater in the ratings?

RQ6. What are other criteria that those who educate engineering and computing students about ESI consider important in exemplary ESI education?

Methods
In phase 1, a large national survey asked faculty who teach engineering and computing students to describe their instructional practices related to ethics and/or societal impacts. Survey participation was solicited via email among authors of papers on engineering ethics, NSF grantees studying engineering ethics education, open calls to the lists of divisions of the American Society for Engineering Education, and mentors of co-curricular groups. The survey invitation methods and response rates are described in detail in [3]. Among 1448 responses, 1222 indicated that they taught students about ESI in one or more of their courses for engineering students and 1082 indicated that they taught students about ESI through co-curricular activities that they mentored. ESI was being taught in an array of different settings using a variety of methods. At the end of the survey, 231 respondents indicated a willingness to participate in interviews on their experiences teaching ESI.

In phase 2 of the study, the goal was to interview individuals who represented high impact ethics education practices. This could have been indicated by the use of multiple assessment methods for ESI learning, high satisfaction with their ability to assess ESI education, teaching a large number of different ESI topics, teaching ESI in a large number of different course types, or insights from their write-in responses. The five members of the research team worked collaboratively to select 47 individuals teaching at U.S. institutions and 5 individuals at institutions outside the U.S. who were invited to participate in interviews. Interview participants from U.S. institutions were compensated $50. From among the 37 interviews, 35 current ethics instructional practices were summarized in 2-page descriptions. This included two programs, 32 individual courses, and one co-curricular setting. Modalities of engineering ethics education spanned first-year introductory engineering courses (n=4), required engineering courses (n=5, including 1 graduate-level), elective engineering courses (n=5, including 2 graduate-level), professional issues courses (n=4), service-focused programs/courses/co-curricular (n=5), capstone design (n=4), and stand-alone courses fully focused on ethics (n=8, including 1 graduate-level). The appendix summarizes these 35 teaching examples. Some of the teaching examples described in the interviews were not summarized because they were not currently being taught or they were not within the U.S. and therefore could not be studied in detail and observed during phase 3 (due to the restriction of funds available for travel).

The goal was to use a type of "customer discovery" process from the I-Corps-L™ model to determine which of the 35 teaching methods warranted further study as potential exemplars of macroethics instruction. To assist in this process, four evaluation criteria were established: (1) likely to have a high impact on student learning; (2) strong assessment methods/protocol used; (3) novel or innovative; (4) transferability/scalability. The fourth criterion was sub-divided into: transferability to other institutions, applicable to a range of disciplines, personal interest in use, belief others in department might use, and belief others at institution might use. Each of these four criteria were rated on a four-point scale: disagree (1), neutral/unsure (2), agree (3), strongly agree (4). A final overall evaluation on level of excitement for including this teaching example in further research employed a 1 (low) to 10 (highest) scale. Raters were also invited to write-in open comments.

The research team of five individuals and the 37 individuals who were interviewed were invited to rate the teaching examples based on the de-identified 2-page summaries. Three members of the research team rated all 35 teaching examples, while the fourth member rated 21 and the fifth member rated 19. The interviewees were each asked to rate six teaching examples; three were intentionally assigned based on course types and/or discipline similar to that of the individual, and three were randomly assigned. In all, 29 individuals rated their assigned cases and one rated an additional group of six. Each of the 35 teaching examples received 8 to 10 ratings, with the majority (n=25) receiving 9. Some raters skipped particular rating categories.

The characteristics of the teaching rater group compared to the other survey respondents are provided in Table 1.

Table 1. Average characteristics of the case interviewees/raters and overall survey pool

Characteristic	Interviewees and raters (n=29)	Other survey respondents (n=1159)
# ESI topics taught in courses	10	5
# course types taught that include ESI topics	2.9	2.2
# methods used to teach ESI in courses	8	5
# methods used to assess ESI learning outcomes in courses	3	2
# settings where believe students in their program learn about ESI	4.3	2.7
% teaching specific ESI topics in courses:		
Societal impacts of technology	93	56
Engineering decisions under uncertainty	83	51
Ethics in design	72	40
Environmental impacts	66	35
Ethical theories	59	23
% teaching ESI in types of courses:		
First-year design focused	35	12
Full course on ethics	24	6
% using particular methods to teach ESI:		
In-class discussion	93	67
Reflection	59	24
In-class debates	55	21
Videos	52	27
Humanist readings	38	8
Think – pair – share	41	13
Service learning	35	12
% assessing outcomes of ESI learning via specific methods:		
Individual reflective essays	62	38
Group-based written assignment	52	32
Opinion on sufficient undergraduate ESI education, %	(n=28)	(n=1103)
Too much, time better spent on other topics	0	1.2
Sufficient amount	17.9	31.0
Sufficient ethics, insufficient broader impacts	7.1	16.4
Sufficient broader impacts, not enough ethics	0	12.1
No, not enough	75.0	39.3
Opinion on sufficient graduate ESI education, %	(n=18^)	(n=861^)
Too much, time better spent on other topics	0	1.0
Sufficient amount	5.6	18.6
Sufficient ethics, insufficient broader impacts	5.6	9.2
Sufficient broader impacts, not enough ethics	11.1	9.6
No, not enough	77.8	61.6

^ lower n due to the fact that some individuals teach at undergraduate-only institutions, or did not feel that they had sufficient knowledge to rate ESI education in the graduate program

Compared to the average survey respondents, the individuals who were interviewed as potential exemplars of ESI education and also rated the teaching examples taught more ESI topics and used a higher number of methods to teach ESI in their courses. This could indicate greater depth and breadth of ESI teaching experience among the rater pool, as would be expected given that they had been selected for interviews based on representing potential exemplars of ESI education. The five ESI topics (among 18 listed on the survey) that were 30% more prevalent among the case raters are highlighted in Table 1, as well as the teaching and assessment methods that were much more widely used. The case raters also more strongly believed ESI education to be insufficient compared to the larger survey population, despite recognizing a higher number of different settings for ESI education for students in their program. This may be indicative of higher standards for what constitutes sufficient ESI education among the case raters in comparison to the average survey respondents. Other potentially important demographic characteristics of the 29 external raters include: 7 held only non-engineering degrees, and 4 held Bachelor's degrees from institutions outside of the US.

Data analysis was conducted using IBM SPSS v. 24. Data analysis began with simple medians, ranges, averages, and standard deviations. Despite the fact that the Likert-type scale data were not continuous nor normally distributed, averages and standard deviations were used to give a basic sense of the central tendency of the rating level and dispersion or level of agreement among the raters. Comparisons among items rated on the 4-point scale were conducted via Pearson chi-square tests, with differences inferred when the 2-sided asymptotic significance was 0.05 or lower. Comparison among the excitement ratings on the 1-10 scale were conducted using non-parametric Kruskal-Wallis tests (for comparisons among multiple categories, such as course type) or Mann-Whitney U-tests (for comparisons among two categories, such as individuals with or without engineering degrees). These non-parametric tests do not require that the data are normally distributed. Correlations were also explored among variables using the Spearman rho correlation, which is a non-parametric measure frequently used with ordinal data.

Results and Discussion

RQ1. Student Learning, Assessment, and Novelty Ratings

The median, mean, and standard deviations of ratings for impact on student learning of ESI, strong assessment, and novelty are summarized in Table 2. Across these categories, impact on student learning ratings were the highest, and assessment the lowest. Two of the learning settings believed to be the most impactful for student learning were programs that were comprised of multiple courses; these programs also had the highest novelty ratings. Cases highly rated for student learning appeared to include a wide range of ESI topics and different ESI teaching methods. This approach appears to align with the Vanasupa et al. Four Domain Development Diagram model [22] for engineering education. The range of ESI topics relates to finding topics of personal interest, showing value across a range of settings, connecting to the broader context, and demonstrating the inter-relationships between different concepts. The range of teaching methods could activate learning across cognitive, affective, social, and/or psychomotor domains. Correlations were statistically significant between ratings of novelty and both the likely impact of the course on students' ESI learning and strong assessment used in the course (Table 2).

Table 2. Student learning, assessment, and novelty ratings and correlations

Rated Category	Median out of 4	Mean (range)	Standard deviation	Correlation learning	Correlation assessment	Correlation novelty
Impact on student learning	3	3.2 (2.3-3.8)	0.78	1.0	0.289^	0.719**
Strong assessment	2	2.3 (1.7-3.3)	0.82	0.289^	1.0	0.366*
Novel / innovative	3	2.8 (2.0-3.8)	0.82	0.719**	0.366*	1.0

Significance (2-tailed) ** $p < 0.001$; * $p = 0.031$; ^ $p = 0.092$

During the interviews, some individuals did not clearly describe or discuss the assessment methods that they used in their courses or other ESI educational settings, resulting in weak descriptions in the two-page summaries (e.g. Appendix, FY4, E3, El1). Standardized and/or validated assessments (e.g. DIT2) were used in courses with high ratings for assessment.

Courses with high ratings in all three categories might be considered exemplars. Two courses had average ratings in the top quartile for all three categories (PI3 and Sv5), with two more courses close to meeting these criteria (Eth2 and Eth4). These courses are highlighted in Table 3.

Table 3. ESI learning settings with high ratings for student learning, assessment, and novelty

Learning setting (Case, Course Title)	ESI Topics	ESI Teaching Methods	Learning rating	Assessment rating	Novelty rating
Sv5-P Entrepreneurship and Humanitarian Engineering	Humanitarian eng, engrg for developing communities, empathy, ethical decision-making, grassroots diplomacy, research ethics, IP, human-centered design, sustainability	Technology-based ventures with partners in developing countries, case studies, discussions, ethical reflection methodology	3.6	2.9	3.8
PI3 Integrated Eng Professionalism Seminar	Issues related to 3-credit design project with industry or academic client	Discussions, debates, current issues; codes of ethics of different organizations, peer learning	3.4	2.8	3.3
Eth4 Social & Ethical Issues in Engrg	Micro and macro ethics, socio-technical, environment	News stories; group discussions; team projects; readings	3.6	2.7	3.0
Eth2 Modern Ethical Issues	Moral literacy framework, ethical theories, biotechnology, synthetic biology	Current events / case studies, discussion-based	3.4	2.9	3.1

RQ2. Disagreement among ratings

The standard deviation in ratings was used as a rough measure of "dispersion" or disagreement among the ratings. The average standard deviation among the 35 ESI teaching settings for student learning impacts, assessment, and novelty were similar (Table 2) at about 0.8, with a range across the 35 teaching settings of 0.3 to 1.2. In some cases there was high disagreement, with ratings spanning all four Likert-type categories (7 cases for student learning, 5 cases for assessment, and 10 cases for novelty). For example, among the student learning ratings the largest disagreement was for a capstone design course (Dsn2). Two comments associated with the low ratings were: "Capstone courses are expected to include ethics but seldom succeed in distinguishing it from a dozen other topics" and "It is not clear how much ethics students actually receive, since it is dependent upon issues that come up in the course of the design process." In contrast, one of the positive comments was: “The course seems to offer … effective ways to show the interconnectedness of technical and non-technical dimensions in design.”

Raters likely had varying standards for novelty/innovation, perhaps based on level of expertise or familiarity with a range of ESI teaching approaches either from personal experience and/or broad familiarity with the literature. Two raters had median novelty ratings of 1.5 across their six teaching examples, compared to another rater with a median novelty rating of 4 across their six ratings. There were also seven raters who used the entire scale of 1 to 4 across the cases that they evaluated.

There were correlations between the average ratings and the standard deviation among the ratings. There was a moderate negative correlation between the average rating for the likelihood that the case would lead to student learning outcomes for ESI and the standard deviation among those ratings (Spearman correlation -0.483, sig. 0.003). This means that there was typically more variation among the ratings for cases with lower average ratings. Similarly, there was a slight negative correlation between the average novelty rating of the case and the standard deviation among the novelty ratings (Spearman correlation coefficient -0.297, sig. 0.083). There was a moderate positive correlation between the median assessment rating and standard deviation among the assessment ratings (Spearman correlation 0.574, sig. <0.001). This implies that there was more variability among the ratings for cases with higher average ratings. The variability among the ratings complicates the process of identifying exemplars of ESI education.

RQ3. Transferability

There were five rating categories that related to transferability; there were weak to moderate positive correlations among all of these rating categories (Table 4). The strongest correlation was between personal interest/potential use and perceived potential use by others in their own department. This indicates perhaps some disciplinary specificity in some of the ratings and perceived uses. Given the correlations among the five transferability categories, these were averaged; the teaching settings with highest average ratings were Dsn1, El5, and Eth4, Dsn2, and Eth1 (average ratings 3.3 to 3.0).

Table 4. Spearman’s rho correlation coefficients among transferability related survey items

Transferability-related survey item	Transferable to other institutions	Others at my institution might use it	Applicable to a range of disciplines	Others in my department might use it	I might use it
Transferable to other institutions	1.000	.399**	.396**	.418**	.291**
Others at my institution might use it	.399**	1.000	.275**	.494**	.427**
Applicable to a range of disciplines	.396**	.275**	1.000	.452**	.463**
Others in my department might use it	.418**	.494**	.452**	1.000	.525**
I am personally interested and might use some of what could be learned from this case study	.291**	.427**	.463**	.525**	1.000

** correlation significant at the <0.001 level (2-tailed)

Personal interest had the largest standard deviation across all of the rating categories (average 1.0). This is not surprising given that individuals teach a variety of courses across a range of disciplines, with personal preferences for ESI topics, teaching methods, and assessment methods. The raters also range in familiarity with ESI education in engineering, and therefore may be more or less familiar with aspects in some of the cases.

RQ4. Overall Interest for Further Study

The median level of rater interest / excitement for including the ESI teaching example as a case study for further research for each of the 35 teaching examples ranged from 5 to 8 (on a 1 to 10 scale), with a median of 7. The teaching settings with the highest average ratings were Eth6-P, Sv5-P, El2, Dsn1, and Eth5 (see Appendix). The level of excitement ratings correlated somewhat with the ratings in the other categories, as would be expected (Table 5). Using these correlations, one might infer that the most important factors for being exemplary ESI teaching settings are high impact on student learning, followed by novelty, and assessment. Correlations with the transferability-related ratings were variable.

Table 5. Correlations of rating factors with overall level of excitement for the teaching example

Other Rated Factors	Spearman's rho correlation
I am personally interested and might use some of what could be learned from this case study	.741**
Likely to have a high impact on student learning	.621**
Novel / innovative	.608**
I think others in my department might use it	.488**
Strong assessment methods / protocol used	.460**
I think others at my institution might use it	.425**
Applicable to a range of disciplines	.391**
Transferable to other institutions	.258**

** correlation significant at the <0.001 level (2-tailed)

Examples of four teaching examples with the largest disagreement among raters and the two teaching examples with the greatest consensus are shown in Table 6. One course had ratings spanning the entire 1 to 10 scale, a clear indication of significantly different personal opinions among the raters. Two of the service-related settings were among the settings with highest disparity of ratings. The two settings with high agreement among the raters were highly rated with a clear ethics focus. There was a moderate negative correlation between the median excitement rating and standard deviation (-0.485 Pearson correlation, sig. 0.003), meaning that there was less agreement (higher standard deviation) for cases with lower ratings.

Table 6. ESI Teaching settings with largest and smallest differences among excitement ratings

ESI Teaching Setting	Notes	Stdev rating	ratings level				
			Min	Q1	Q2	Q3	Max
Sv3 Service-Learning Projects	All ranks, electives	3.2	1	5.8	7	8.3	10
PI4 Eng Ethics & Professionalism	All majors, 1 credit	2.8	1	5	7	8	9
Sv2-CoC Engineers Without Borders	Co-curricular	2.7	2	5.3	6	8.8	9
Eth8 Impacts Modern Technology on Society	All majors, elective	2.7	1	2	6	6	8
Eth6-P Macroethics Education	Program	0.9	6	8	8	8	9
Eth2 Modern Ethical Issues	Philosophy crs, sem	0.7	6	7	7	7.8	8

RQ5. Impact of Course Type, Course Instructor, Rater on Ratings

It was found that the ratings varied among different types of ESI teaching settings; Table 7 shows the average ratings for the different modalities of ESI instruction. The service settings had the highest rating for student learning, professional issues courses the highest rating for assessment, full ethics courses were perceived as the most novel/innovative, and engineering electives were perceived as the most transferable to other institutions. In a Kruskal-Wallis test to compare ratings on excitement for further exploration, differences were marginal (sig. 0.051), with the most interest for full ethics courses and lowest for first-year courses.

Table 7. Average ratings for different course types

Rating Category	FY	Eng Req Courses	Eng Electives	Service	Prof Issues	Capstone Design	Full Ethics
Impact on student learning outcomes*	3.0	2.9	3.2	3.8	3.0	3.6	3.5
Strong Assessment**	2.1	2.2	2.4	2.2	3.0	2.3	2.3
Novel/innovative*	2.5	2.8	2.3	3.0	2.8	3.0	3.1
Transferable to other institutions*	3.0	3.0	3.2	2.8	2.5	2.9	3.0
Applies to range of disciplines	3.5	2.8	3.3	3.2	3.5	2.8	3.5
Personal interest and might use	2.5	2.8	3.0	3.0	2.9	3.0	3.0
Others in department might use*	2.8	2.5	2.4	2.6	2.6	2.5	2.3
Others at my institution might use*	2.3	3.0	2.8	3.0	2.6	2.8	2.8
Level of excitement for further study$^{.051KW}$	6.0	6.2	6.6	6.8	6.5	6.4	7.1

Pearson chi-square test: ** $p<0.001$, * $p < 0.05$; KW = Kruskal-Wallis

Within the group of individuals who educate engineering and computing students about ethics, there were both engineering faculty (the majority, 83%) and some non-engineering faculty. The disciplinary backgrounds of the course instructor made a difference in how the ethics educational settings were ranked for student learning impact, novelty, and excitement for inclusion in further research (Table 8). This is perhaps not surprising, since those outside of engineering who teach ethics to engineering and computing students are more likely to be "experts" trained in ethics. In comparison, many engineering faculty have learned about ethics less formally.

Table 8. Average ratings with statistically significant differences based on whether the instructor or rater was an engineer or non-engineer

Rated Characteristic	Ethics Educators		Rater	
	Engineer	NonEngr	Engineer	NonEngr
Impact on student learning	3.09**	3.51	3.20*	3.01
Strong assessment protocol	--	--	2.4**	2.0
Novel / innovative	2.75*	3.05	--	--
Applicable to a range of disciplines	--	--	3.19**	3.01
Personally interested	--	--	2.85**	2.34
Excitement for including in further research	6.23^{MW**}	7.02	--	--

** Pearson chi-square asymptotic significance 2-sided <0.005; * <0.05; MW = Mann-Whitney test
-- Not significant difference

When ratings were explored for potential differences based on the discipline of the rater, engineers rated the likelihood to impact student learning, strong assessment protocol, personal interest, and applicable to a range of disciplines higher than non-engineering raters. Again, this result could suggest that non-engineering educators who specialize in ethics are likely to have higher standards for what constitutes exemplary ethics instruction.

Due to potential interactive effects, the impact of instructor type was explored specifically with the full ethics courses, where four were taught by individuals with non-engineering backgrounds and four by individuals with engineering backgrounds. The courses taught by non-engineers were rated on average as more novel (3.5 vs. 2.8; sig. 0.04), more likely to impact student learning (3.6 vs. 3.3; sig. 0.003), and with more excitement for further study (7.6 vs. 6.5;

independent samples Mann-Whitney U Test sig. 0.001). These results provide encouragement for engineering faculty to partner with non-engineering faculty to improve the ethics education of engineering and computing students.

RQ6. Other Important Considerations

The write-in comments allowed raters to expound on their interpretations of exemplary characteristics and these responses revealed a range of perspectives regarding the importance of theoretical grounding, the role of industry experience, and ability to scale particular practices.

In regards to ethical theory, four of the non-engineering raters made comments on one or more teaching examples that implied that they believe ethical theories are a critical aspect of ethics education. For example, "Few engineering faculty have a firm grasp on normative theory, and that foundation is crucial for students." Two engineering raters questioned the ability of engineering educators to effectively teach courses that relied heavily on ethical theory, mirroring the concern of the non-engineering educator. There were also statements by some engineering educators that appeared to discount the need or wisdom of including ethical theory in the ESI education of engineering/computing students.

Raters also commented on the role that real-world experience in engineering industry settings can play in ESI education. This included the industry experience of both instructors and students (via co-ops or in a graduate level course). For example, "I really like that they use industry veterans, but this may not be possible at all schools…."; also, "Major (minor) 'con' is the need for previous industry experience, on the students' and instructor's parts, to have the most beneficial impact on ethics education."

There were also comments that related to concerns with class-size, such as whether the teaching methods could be used in classes with larger numbers of students. It appeared that some raters down-graded ESI teaching examples that were applied in small class-sizes, e.g. "the numbers (20 students) weakens the possible impact." Others seemed to question educational effectiveness in larger settings (e.g., "the idea that in a lecture one can discuss a case with 200+ students seems preposterous").

Summary and Implications

This work gathered feedback on 35 ESI teaching examples in order to evaluate the presence of potential "exemplars" for further study. It is proposed that exemplary ESI teaching would have a strong impact on student learning, employ strong assessment methods, be somewhat novel/innovative, and/or be transferable to other settings. Therefore, individuals were asked to rate the teaching examples on these characteristics using a 4-point scale, as well as providing an overall rating of their level of excitement for additional study of the ESI teaching setting on a 10-point scale. This rating process resulted in some teaching examples being highly rated across multiple criteria (such as PI3, Sv5, Eth2, Eth4). However, in some cases high levels of rater disagreement were evident, with ratings ranging from 1 to 4 for some characteristics (e.g. E3, E4, Sv2-Co, Sv4, Dsn4). Supported by the write-in comments, this points to differences in what individuals perceived to be impactful educational settings for ESI, as well as differences of opinion in the effectiveness of assessment strategies, novelty, and transferability. While some of these differences might be attributable to the brevity of the course descriptions and therefore uncertainty among the raters, in other cases clear differences were evident. For example, some believe that ethics education must be grounded in ethical theory, while others believe this to be unnecessary. In addition, ESI issues that arise "naturally" in the context of engineering projects (either in community service programs, projects for clients, or capstone design) were perceived as being particularly impactful by some, but perhaps falling short by others.

What was missing from all of the two-page summaries of the ESI teaching settings was evidence of student learning. This is a key element in the next phase of the research. A sub-set of courses have been selected for further study based on the exemplary rating process. For this sub-set of learning environments, the research team will gather data from students using pre/post surveys and examine student work using rubrics. A smaller number of settings will be directly observed, such as viewing student discussions or role plays and using an observation protocol that includes looking for evidence of student resistance; student focus groups will be conducted at these sites. Perhaps even more meaningful will be surveys of engineers and computing professionals working in practice, asking them to reflect back as "alumni" of various ESI learning experiences. The research team is also interviewing faculty to gather their perceptions. These multiple methods enable triangulation to judge exemplary ESI learning settings.

The rating results from the current study indicate a low probability that there will ever be a "one size fits all" approach to ESI education. Rather, there are a range of good practices for various settings and disciplines that provide models to enable individuals to craft ESI teaching practices that they believe are most appropriate to their context. For example, some disciplines are likely to include sustainability as a required topic for ethical exploration. Some institutions will want to ensure consideration of elements such as social justice. Other institutions may face curricular and personnel challenges and be restricted in the courses that they can offer and whom they can task with teaching them. There may be value in students experiencing ESI education from the perspective of both engineers and non-engineers. Different perspectives and teaching approaches for ESI were evident among these groups, and this range of experiences could ultimately enhance students' ethical reasoning abilities, impact their attitudes, and effect their behaviors.

It appears that one could not expect to achieve adequate education on ESI within a single course. A single course simply cannot cover the breadth of important microethics and macroethics topics and reach reasonable levels of cognitive and affective depth. Integrating ESI across a range of courses in a deliberate manner can reinforce and build on ideas. Including ESI across the curriculum has been advocated as an effective way to foster ethical development in an already dense technical curriculum [23, 24]. One strategy would be to introduce the importance of ESI in a first-year course, then set a foundation for ethical behavior and reasoning based on ethical theories in another course during the middle years. A professionalism course and/or capstone design in the senior year could reinforce how ESI issues permeate engineering practice. This thoughtful and intentional design of ESI education must occur at a programmatic level within each degree program, including both undergraduate and graduate degrees, to ensure that the curriculum meets targeted learning objectives. One difficulty may be getting faculty to agree on appropriate ESI learning outcomes. A second challenge is getting faculty buy-in to integrate ESI in a range of courses, as well as determining if faculty are equipped to effectively teach ESI. The change in the ABET criteria related to ESI (which requires "an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts") might provide an ideal opportunity to bring faculty together to develop an effective strategy for undergraduate ESI education in engineering; perhaps these deliberations can be extended to the graduate level as well.

Acknowledgements
This material is based on work supported by the National Science Foundation under Grant Nos. 1540348, 1540341, and 1540308. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

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Appendix. Summary of 35 ESI Teaching Contexts and Average Transferability Ratings

Type	Case	Course Title	Student ranks	# students	Institution Control, Carnegie	Notes	Transferable to other institutions	Applicable to range disciplines	Personal interest and might use	Others in my dept might use	Others at my instit might use
First-year (FY)	FY1	Introduction Chemical Engrg	FY	30-42	Priv, M		3.2	3.3	2.6	2.8	2.7
	FY2	Introduction to Engrg II	FY		Relig, M	2 cr	3.3	3.3	3.1	2.5	2.1
	FY3	Introduction to Engrg 1	FY	24/sect	Publ, R2	2 cr	3.1	3.5	2.4	2.6	2.6
	FY4	Introduction to Engineering	FY	24/sect	Assoc.		3.0	3.4	2.2	2.2	2.3
Engineering required courses	E1	Materials	Junior	30/sect	Relig, D		3.1	3.3	2.4	2.6	2.7
	E2	Heat and Mass Transfer	Junior		Priv, M		3.1	2.4	2.3	2.1	2.7
	E3	Dynamic Systems 2	Senior		Priv, M		3.0	3.1	2.7	2.8	2.8
	E4	Biostatistics	Graduate	8-20	Publ, R1		3.1	2.9	2.4	2.4	2.7
	E5	Sustainable civil eng dsn	Soph	40	Priv, M	2 cr	3.1	2.9	2.8	2.4	2.6
Engineering elective courses	El1	Your idea, your invention	FY, soph		Publ, R1		2.9	3.2	2.3	2.2	2.7
	El2	Sustainable energy	Jr/Sr	40	Publ, R2		3.2	2.9	3.4	2.8	2.4
	El3	Mgmt radioactive matls	Graduate	10-20	Publ, R1		3.0	2.8	3.0	2.3	3.0
	El4	Mentoring novice researchers	Graduate	10-12	Publ, R1	Summer	3.1	3.2	2.4	2.0	2.1
	El5	Cost, schedule, and risk	Jr/Sr	25-30	Publ, R1		3.7	3.7	3.0	2.8	3.0
Capstone design	Dsn1	Environmental Engrg Design	Senior	40	Publ, M	2Q	3.4	3.3	3.4	3.1	3.0
	Dsn2	Electrical & computer Design	Senior	35	Priv, B	2 sem	3.3	3.3	2.9	2.6	2.9
	Dsn3	Paper engrg design	Senior	15-20	Publ, M	2 sem	2.7	2.9	2.6	2.4	2.4
	Dsn4	Biomedical Engrg Practicum	Junior	24	Publ, R1	2 sem	2.3	2.1	2.6	1.9	2.6
Professional issues	PI1	Ind & Eng Mgmt Profession	Senior		Publ, Spec	1 cr	3.0	3.0	2.4	2.5	2.5
	PI2	Prof Issues Eng & Con Mgmt	Senior	20/sect	Priv, B		3.1	3.6	2.8	2.4	2.7
	PI3	Integ Eng Profession Seminar	FY-Sr	34-40	Publ, M	1cr/sem	2.3	3.2	3.1	2.7	2.7
	PI4	Eng Ethics & Professionalism	Senior	22	Relig, M	1 cr	2.2	3.3	2.8	2.1	2.1
Service-focus	Sv1	Eng & SCD	So-Grad		Publ, R2		2.4	2.7	2.9	2.3	2.6
	Sv2[Co]	EWB Engrs Without Borders	FY-Grad		Publ, R1		3.5	3.1	2.5	2.1	2.9
	Sv3	Service-Learning Projects	FY-Sr	200/sec	Publ, R1		3.1	3.4	2.7	2.4	2.8
	Sv4	Honduras design project	FY-Grad	25-30	Publ, R1	2 sem	2.6	3.1	2.6	2.6	2.6
	Sv5[P]	Entrep&Humanit Eng prog.	FY-Grad	40-50	Publ, R1	5 crs	2.3	3.1	3.1	2.6	2.4
Full ethics	Eth1	Software / Bioengrg Ethics	Grad		Relig, D	Req	3.6	3.5	2.9	2.6	2.4
	Eth2	Modern Ethical Issues	Junior	25-50	Publ, R1	Elect	3.1	3.5	3.0	2.4	2.6
	Eth3	Engineering Ethics	Jr/Sr	25	Publ, R1	Elect	3.1	3.2	2.6	2.2	2.1
	Eth4	Social & Ethical Issues Eng		60	Relig, R2	Option	3.0	3.6	3.4	2.8	2.9
	Eth5	Ethics in Software Design	Junior	21	Relig, B	Req	3.0	2.5	3.1	2.2	3.0
	Eth6[P]	Enacting Macroethics	FY-Sr	Var.	Publ, R2	Elect	2.3	3.2	3.2	2.2	2.4
	Eth7	Eng Ethics	Junior	8	Relig, M	Req 1cr	2.8	3.4	2.3	1.9	1.9
	Eth8	Impacts Modern Tech Soc'y	FY?	20	Publ, R2	Elect	3.2	3.4	2.4	1.8	2.6

[Co]=Cocurricular activity; [P]=program; Carnegie B=Bachelor's, M=Master's, D=doctorate, R1=highest research, R2=higher research, Spec=specialty

Appendix. Summary of 35 ESI Teaching Contexts and Summary of Student Learning, Novelty, and Assessment Ratings

Case	ESI topics	ESI teaching methods (examples)	Student Learning Rating	Novelty Rating	ESI Assessment methods (examples)	Assmt rating	Median Interest Rating (range)
FY1	Safety, sustainability, prof resp.	History team project, tour,	3.1	3.0	Final exam	2.1	7 (4-8)
FY2	Prof practice issues	Dilemma game, create rules of practice	3.1	3.3	Team creative proj	2.6	7 (4-9)
FY3	Code, env impact, eth decisions	Cases disasters/current events, disc, dsn	2.9	2.2	Class participation	2.0	5 (3-10)
FY4	Ethics, energy use, contemporary issue	Projects, industry stories, reading, SL	2.7	2.1	?	1.8	5 (3-8)
E1	Data truthfulness; community outreach	Collab, outreach extra credit	2.3	2.4	Extra credit refl essay	2.4	5 (2-9)
E2	Safety, broader impacts, dsn choices	Case study w/ video, discussion	2.7	2.6	HW, project	2.1	6 (1–8)
E3	Safety, prof issues, legal vs. moral	News, personal exp. stories	2.8	2.6	?	1.7	6 (2–8)
E4	RCR, animal welfare, human research	Discussions, activities, calculations	3.0	3.1	Wkly learning report	1.9	7 (3-10)
E5	Social impacts, stakeholders, sustain.	Case studies, discussions, role plays	3.2	2.6	Reflections	2.4	7 (2-8)
El1	Community needs, empathy	Workshop, team-based service projects	3.1	2.4	?	1.9	6 (3-8)
El2	Soc, env, econ, political impacts	Debates, discussions, videos	3.4	3.3	Team videos	2.6	8 (4-9)
El3	Env impact, risk perception, public	Readings, writing, discussions	3.3	3.2	Blog on readings	2.6	7 (2-10)
El4	RCR, data fabrication, mentoring	Case studies, group discussions	3.0	2.0	Papers on ethics in proj	1.8	5 (1-7)
El5	Safety, uncertainty, risk, failures	Case study, current events, discussions	3.3	2.6	Final project	2.6	7 (4-10)
Dsn1	Social justice, NIMBY, conservation	Role play, guided discussion, case studies	3.6	2.9	HW assignment	2.2	7 (6-9)
Dsn2	Design, legal issues, systems approach	Dsn projects w external clients; case study	3.2	2.7	Reflection, ltrs	2.4	7 (3-10)
Dsn3	Safety, environm impact, conservation	Video case studies, discussion, dsn project	2.8	2.7	Dsn proj AA	2.7	6 (4-8)
Dsn4	Design failure, patient impact	Hospital rotation, case studies from prof.	3.3	2.8	Posters	1.9	5.5 (2-9)
PI1	Code ethics, IP, licensure	Guest speakers	2.6	2.3	DIT2, team assessments	3.3	6 (2-7)
PI2	Prof practice issues	Scenario discussions, guest speakers	3.3	2.8	Discn rubric	3.2	6 (3-9)
PI3	Prof practice; dsn w/ industry clients	Discussions, debates, peer learning	3.4	3.3	Refl journals	2.8	7 (6-10)
PI4	Bias, company values, social attitudes	Case readings, discussions, workplace eth.	3.0	2.9	Reflection	2.4	7 (1-9)
Sv1	Cultural awareness, community involv	Guest speakers, case sty, discus., readings	3.6	3.0	Projects	1.8	7 (2-8)
Sv2[Co]	Poverty, dev communities, non tech	Real projects w/ communities; discussions	3.0	2.1	Deliverables	1.8	6 (2-9)
Sv3	Human centered design	Real project w/ clients; ethics lecture, disc	3.3	3,3	Reflections	2.8	7 (1-10)
Sv4	Poverty, culture, socio-tech	Dialogue, guest speakers, discussions	3.4	3.0	Reflection	1.8	6 (2-9)
Sv5[P]	Diplomacy, culture, IP, sustain.	Cases, ventures w/ developing commun.	3.6	3.8	Reflection, case	2.9	8 (5-9)
Eth1	Microethics, macroethical issues	Case studies, readings, discussions	3.4	2.5	Refl; papers	2.8	8 (3-9)
Eth2	Eth theories, biotech, moral literacy	Current events / case studies, discussions	3.4	3.1	Team presentation	2.9	7 (6-8)
Eth3	Microeth, sociotech, eng disasters	Case sty, debate, role plays, videos	3.2	2.6	Reflection, code	2.6	6 (4-8)
Eth4	Micro/macro, sociotech, environm	News, team projects, discussions, reading	3.6	3.0	Gp video, poster	2.7	8 (5-9)
Eth5	Privacy, IP, equal access, soctech	Role play, case study, discussions	3.8	3.5	Gp project	2.5	7.5 (6-10)
Eth6[P]	Social justice, diversity, empathy	Design projects, cases, discussions	3.8	3.8	Project reports	2.0	8 (6-9)
Eth7	Weapons, soctech, engrs responsibility	Readings, discussions, news stories	2.7	2.6	Reading reflections	2.0	6 (1-8)
Eth8	Weapons, environ, energy, medicine	Read & discuss 10 cases	2.7	2.4	Reports, quizzes	1.9	6 (1-8)

[Co]=Cocurricular activity; [P]=program