Institutional Variations in Ethics and Societal Impacts Education: Practices and Sufficiency Perceptions Among Engineering Educators

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Abstract

This research aims to increase our understanding of institutional variations in the education of undergraduate engineering/computing students about ethics and societal impacts (ESI). In alignment with Input-Environment-Output models and Lattuca and Stark's Academic Plan Model, it was expected that differences in institutional cultures could manifest in the ESI educational perceptions and practices of faculty. About 1400 engineering educators responded to an online survey in spring 2016. From among the responses, there were 22 institutions represented by 9 to 24 respondents who spanned 5 or more disciplines at each institution. There were not significant differences in the percentage of institutionally-grouped respondents who taught the majority of ESI-related topics (e.g. safety, environmental protection). However, institutional differences were found for a few ESI-related topics such as social justice (0 to 63%) and poverty (0-46%). Differences in the curricular models for ESI education were also evident among the 22 institutions; e.g. ESI education in first-year design-focused courses, professional issues courses, and full courses on ethics varied. The percentage of the faculty who believed that undergraduate students in their program received sufficient education on ethics ranged from 90% of the faculty respondents at one institution to only 14% at another. At the two high and low 'outlier' institutions for ethics educational sufficiency perceptions, mission and vision statements, institution level outcomes, and course requirements for undergraduates were explored using online documents. The institution with the lowest sufficiency rating integrated ethics education into its objectives and teaching within engineering less than the two institutions where the greatest percentage of faculty viewed ethics education in engineering as sufficient. However, at the institution where only 20% of the faculty viewed undergraduate ethics education as sufficient, the integration of ethics education for engineers and support from the institutional mission appeared strong. The results point to the importance of future qualitative research to explore the extent to which faculty perceive the culture of their institution, college/school of engineering, and/or engineering department as supportive of ESI education for undergraduate students.

Introduction

The education of engineering and computing students about ethics and societal impacts (ESI) is critically important [1-8], but also widely viewed as deficient [9]. The National Academy of Engineering (NAE) [4] and National Science Foundation (NSF) [10] have devoted resources and attention to improving the ethics education of students. This includes both microethics, or individual responsibilities, and macroethics, addressing the "role of engineers in societal implications about technology" and the broader societal and environmental responsibilities of the profession [11].

Although accreditation requires some degree of ESI education [7,8], the precise nature is not constrained and seems to be largely at the discretion of individual programs and their faculty. Lattuca and Stark's Academic Plan Model [12] describes faculty teaching choices. It is similar to other types of Input-Environment-Output (IEO) models. Based on these models, ESI teaching practices (the ‘output’ of what is taught) would be influenced by personal factors (largely inputs) and environmental factors (external environments such as accreditation standards as well as local departmental or institutional factors). Interviews with engineering faculty and survey responses identified environmental factors among the challenges they faced in teaching ESI to engineering and computing students [13, 14].

The “environment” part of the IEO model encompasses various experiences at the institution that contribute to shaping if and how an individual teaches ESI. The environment includes the immediate department or unit (typically organized by discipline, such as civil and environmental engineering), college (such as engineering, inclusive of multiple disciplines), and the institution as a whole. The majority of U.S. higher education institutions (85%) require that all undergraduate students meet a common set of learning outcomes, including ethical reasoning skills (75%), civic engagement (63%), and knowledge of sustainability (27%) [15]. A national study found that 36% of the faculty from public universities had given at least one assignment in the past year that required students to discuss the ethical or moral implications of a course of action; this was much lower than the 44% of faculty at private universities and 48% of faculty at four-year Catholic colleges that indicated the same [16]. Thus, ESI teaching practices for engineering might vary at the institutional level.

The extent to which faculty control the content in their courses varies. The overall curriculum design to ensure that accreditation requirements are met may call for the inclusion of ethics and/or considerations of the societal impacts of technology within particular courses [7, 8]. Some institutions and disciplines require that all students take the Fundamentals of Engineering (FE) exam prior to graduation [17], and may therefore prepare their students for the multiple-choice questions on microethics that are expected on the exam. ESI teaching may also be impacted by student resistance, which has been noted in professional issues courses [18, 19]. This resistance is perhaps less likely at institutions where the overall culture embraces the importance of ethics education.

The literature does not include detailed comparisons of the ESI educational practices in engineering at different institutions, particularly in regards to macroethical issues. Previous research found differences between religiously-affiliated and secular institutions in the extent that some ESI topics were taught (e.g. risk and liabilities, poverty, social justice, safety) and faculty perceptions of ESI educational sufficiency [20], but these findings were based on pooled responses across 60 religiously-affiliated institutions and 358 secular institutions. Comparisons at the level of individual institutions were not found.

Research Questions

The specific research questions explored in this work were:

RQ1. To what extent do the ESI topics that are taught in courses for engineering and computing students differ among individual institutions?

RQ2. To what extent do faculty perceptions of the course types where ESI topics are taught to undergraduate students in their program differ among institutions?

RQ3. To what extent do faculty perceptions of the sufficiency of the ESI education of undergraduate students in their program differ among institutions?

RQ4. What differences are evident in the institutional support and teaching practices for ESI at the two institutions with the highest and lowest percentages of faculty who believed the ESI education of undergraduate engineering/computing students in their program was sufficient?

Methods

The study and its instruments were reviewed by an Institutional Review Board for human subjects research and deemed exempt.

Survey. Online surveys were developed to explore the ESI instructional practices and perceptions among faculty who teach engineering and computing students in courses and co-curricular activities. A literature review led to pilot versions of the surveys which were administered at three institutions. A small number of faculty were interviewed after taking the surveys. This resulted in two surveys created in Qualtrics: (1) curricular and (2) co-curricular. The survey questions used to answer the research questions in this study were the same on both surveys, just presented in a different order. Individuals could elect to skip any of the questions on the surveys. The survey asked individuals to indicate all of the ESI-related topics that they taught in courses for undergraduate or graduate students, with 18 response topics listed plus 'other (describe)' and none (see specific topic list in Appendix). Later in the survey, individuals were asked, "In your opinion, do undergraduate engineering/computing students in your program receive sufficient education on the societal impacts of technology and ethical issues". This was followed by a question that asked, "Where do you think undergraduate students in your program learn about the societal impacts of technology and/or ethics?" Response options for this question included 8 types of courses, other, and unsure (see specific list in Appendix). Both surveys ended with demographic items related to individual and institutional characteristics. Individuals were asked to indicate all of the engineering/computing disciplines that they taught. Respondents were provided an open response box to fill in the name of their institution.

Respondents. Individuals responded to the surveys from February to May 2016. Individuals who authored papers or received grants from the National Science Foundation related to ethics education in engineering or computing were emailed an invitation to the *curricular survey*. Links to the curricular survey were also distributed to lists of four divisions of the American Society for Engineering Education (ASEE): Engineering Ethics; Liberal Education / Engineering & Society; Community Engagement; Educational Research and Methods. To recruit faculty not specifically engaged in ESI education, email invitations to the *co-curricular survey* were sent to individuals who mentored co-curricular engineering groups (e.g. American Society of Civil Engineers, Society of Women Engineers) and lists of mentors of university chapters of professional societies (e.g. Engineers Without Borders (EWB), American Institute of Aeronautics and Astronautics (AIAA)). Further details on survey distribution have been published [20, 21]. There were 1448 respondents, including individuals who skipped particular survey questions; 73% took the co-curricular survey and 27% the curricular survey. We do not expect that the same individuals took both surveys; however, the identity of all respondents was not known, since they could take the survey anonymously, so this is possible.

Data Analysis. The research goal was to explore individual institutional cultures. There were 19 institutions with 11 to 24 survey respondents; 17 public and two private. Three additional institutions were selected from among eleven with nine respondents each and added to the analysis group in order to increase the range of institutional characteristics (one private, one religiously-affiliated, and one with a specialty service-learning program). These 22 institutions represented 300 respondents in total (Table 1). The basic Carnegie classifications [22] of the 22 institutions were: 15 with very high research activity (RU/VH), five with high research activity (RU/H), one Master's larger program (M), and one special focus: engineering (spec). The undergraduate program classifications (IPUG) were: 12 professions plus arts & sciences (Prof+AS), eight balanced arts & sciences/professions (Bal), two professions focus (Prof). Total institution degrees conferred were grouped into three size ranges: four large (12,000 or more), 13 medium (3,000-12,000), and five small (<2,000). The 22 institutions covered all eight geographical regions, clustered into: six New England+Mid East, five Great Lakes, five Plains, three Southeast, and three West. All 22 institutions included departments of mechanical, electrical, and civil engineering (some combined with related elements including aerospace, computing, and environmental, respectively), and 21 included chemical engineering.

Table 1. Summary of Institutional Characteristics in Study

Institution Pseudonym	Control	Basic	IPUG	Size	Region	# survey respondents	% co-curricular survey
VH-L	Public [L]	RU/VH	Prof+AS	Large	Mid East	21	62
VH1	Public [L]	RU/VH	Prof+AS	Med	Great Lakes	20	35
VH2	Public [L]	RU/VH	Prof+AS	Med	Southeast	15	53
VH3	Public	RU/VH	Prof+AS	Med	Southeast	14	64
VH4	Public [L]	RU/VH	Prof+AS	Med	Southeast	13	85
VH5	Public [L]	RU/VH	Prof+AS	Med	Plains	12	100
VH6	Public [L]	RU/VH	Prof+AS	Med	Plains	12	83
VH7	Public [L]	RU/VH	Prof+AS	Med	Plains	11	91
B-L1	Public [L]	RU/VH	Bal	Large	Southwest	17	82
B-L2	Public [L]	RU/VH	Bal	Large	Great Lakes	15	60
B-L3	Public [L]	RU/VH	Bal	Large	Great Lakes	11	64
VH-B	Public [L]	RU/VH	Bal	Med	Mid East	13	38
H-B	Public	RU/H	Bal	Med	New England	9	100
H-Pf-S	Public	RU/H	Prof	Small	Rocky Mts	24	46
H-Pf-S2	Public	RU/H	Prof	Small	Great Lakes	11	45
H-S	Public	RU/H	Prof+AS	Small	Plains	19	68
Spec-S	Public	Spec.	Prof+AS	Small	Plains	11	100
MS	Public	Master's	Prof+AS	Med	Far West	12	58
Pr-L-B	Private [L]	RU/VH	Bal	Med	Mid East	9	78
Pr-B	Private	RU/VH	Bal	Med	New England	11	73
Rel-B	Private-Rel	RU/VH	Bal	Med	Great Lakes	9	67
Pr-H-S	Private	RU/H	Prof+AS	Small	New England	11	82

[L] Land Grant

Notes on labels in "institution" column:

VH – Carnegie designation as Very High research activity, H – High research activity
Pf – Professions-focused curriculum, B – Balanced arts and sciences + professions
Rel – religiously-affiliated private institution, Pr – Private institution
Spec – special focus institution, MS – Master's university
L – Large (> 12,000 students); S – Small (< 2,000 students)

Statistical analyses of the data were conducted using IBM SPSS v25. Tests to compare frequencies were Pearson chi-square tests; differences were inferred when the asymptotic significance (2-sided) was 0.10 or less. This represents a 10% chance of making a Type I error, and selection of this significance level for analysis is not atypical for small datasets [23]. Non-parametric tests were used to compare differences in the number of ESI topics taught or number of course types including ESI (e.g. Kruskal Wallis). Non-parametric tests do not require normally distributed data and are suitable for data from small samples of ordinal or continuous data; these tests were therefore appropriate to assess if there are significant differences in numerical dependent variables among categorical independent variables (i.e. institution) [24,25].

Institutional context. Institutional website elements were explored using standard document analysis methods [26] in an effort to explain high outliers of institutions where particular ESI topics were taught. Document analysis is a valuable method for triangulation in mixed-methods research [27]. Additional research on institutional context was conducted for four institutions, the two with the largest and two with smallest percentage of respondents who rated undergraduate ethics education as sufficient. The catalog from each institution for the 2015-2016 academic year was acquired from the institutional website. The requirements for particular course types among the curricula were identified. Document analysis involves an iterative process that combines content and thematic analysis [27]. For content analysis, the information was organized into categories related to the research questions, which were ESI topics identified as *a priori* themes. Thematic analysis involved pattern recognition across the themes through a focused examination of the data and how it fits into the category construction. This analysis procedure was completed for the institutional and engineering mission statements since they serve as important influences on the curriculum and embodiments of core values [28]. The learning objectives for the institution, college, and/or engineering department were also analyzed.

Results and Discussion

RQ1. ESI Topics Taught in Courses

Individuals taught a median of five ESI topics in their courses (range 0 to 18), based on their selections among the 19 options listed on the survey. Across the 22 institutions, this ranged from a median of two to seven ESI topics (see Appendix). Differences among the institutions were not statistically significant (likely due to the wide variation among the respondents from each institution). There was a moderate correlation among the percentage of the institutional respondents who took the curricular survey and the median number of ESI topics taught at the institution (correlation coefficient 0.42). This is not surprising as the invitations to the curricular survey were sent to individuals known to be active in engineering ethics education or groups with an interest in ESI and therefore more likely to integrate an array of ESI topics into their teaching, while the mentors of co-curricular activities likely had ESI instructional practices that were more typical of engineering faculty.

Only five of the 19 ESI topics had statistically significant differences in the percentage of institutional respondents who taught the topic in their courses: social justice, societal impacts, engineering and poverty, code of ethics, and ethical theories (Table 2 and Appendix).

Table 2. Summary of differences in prevalence of teaching ESI topics among 22 institutions

ESI Topic	Pearson Chi-Square Asymptotic Significance (2-sided)	% faculty; highest institution	% faculty; lowest institution(s)
Social justice (SJ)	<.001	63; Pr-L-B	0; H-Pf-S2, H-S, Rel-S
Engineering and poverty	.013	46; VH4	0; VH3, VH-5, VH-B, H-B
Societal impacts of eng/technology	.058	71; H-Pf-S	9; VH7
Ethical theories	.063	55; VH1	0; VH5, H-B, Rel-B
Codes of ethics	.053	70; Spec-S	0; VH4

Few respondents at the majority of institutions (≤11% at 12 of 22) taught engineering and computing students about social justice (SJ). Poverty issues related to engineering were also not widely taught (11% or fewer respondents at 16 of the 22 institutions). Teaching poverty correlated with teaching SJ among the respondents (phi coefficient for association among these binary variables 0.482, 2-tailed sig. <0.001; the largest correlation among any of the ESI topics).

There were three institutions where 36% or more of the respondents taught both SJ and poverty issues. This included one private institution (PR-L-B), one technically-focused university (H-Pf-S), and one public institution (VH4). One of these institutions (H-Pf-S) was unique in having a large percentage of the respondents who participated in the curricular survey and 25% who reported teaching humanities and social science (HSS) courses for engineering students. None of the institutions had mission statements that included SJ (as can be found at some Jesuit-affiliated institutions [29]). However, SJ language was found at the websites for these three institutions. At VH4, news stories described that the university required all freshmen to take a SJ course and that resident assistants at the dormitories were required to demonstrate a commitment to SJ. Thus, SJ language and norms appear common at the institution. Institution Pr-L-B had a community development and SJ program, as well as advertising a SJ career fair. Institution H-Pf-S indicated that residence life promoted the importance of diversity and SJ; in addition, engineering-focused HSS electives include SJ. Thus, institution-level initiatives appear to foster SJ ideals at the three institutions. In regards to poverty, all three of these institutions had student chapters of EWB (as did 20 of the 22 institutions) and two had student chapters of Engineering World Health, EWH (8 among the 22 institutions had EWH chapters). Nothing stood out among these three institutions in regards to institutional culture around poverty issues. Rather, it may be that poverty is a good illustration of inequitable access to resources that typifies SJ concerns.

The societal impacts of technology is generally a topic that is widely taught to engineering and computing students (overall 50% of 1336 survey respondents taught this topic, the second most frequently cited among the 19 ESI topics on the survey). This is not surprising given that the ABET requirements for accrediting engineering degrees requires students graduate with an understanding of the societal context of engineering (2000-2018 Criterion 3 outcome h; currently Criterion 3 outcome 4 [7]). The three institutions that were much lower than the others in the percentage of faculty teaching engineering/computing students about societal impacts were all land-grant public institutions with very-high research activity, the undergraduate program characterized as professions plus arts & sciences focus, and medium size (9-20% at VH2, VH5, VH7). One of these institutions had the lowest median number of ESI topics taught per person among the 22 institutions explored in detail. This may indicate that the respondents from this institution were more focused on technical elements in their teaching.

Engineering codes of ethics is another topic that was fairly commonly taught among survey respondents overall (42%, fifth highest among the 19 ESI topics on the survey). At one public institution (VH4), none of the 11 individuals who answered this survey questions taught the code of ethics; this was somewhat surprising given that these individuals did report teaching typical courses where ethics is taught (e.g. senior capstone design, first-year engineering courses). However, the individuals from VH4 who responded to the survey seemed more focused on macroethical issues – since this institution was among the group with highest percentage of respondents teaching SJ, poverty, and the societal impacts of technology. One of the other institutions that was a low outlier (VH5, 17% of the 12 respondents taught about the code of ethics) had a low number of ESI topics taught by respondents (avg. 2.5 versus 5.5 among survey respondents overall; 3 taught no ESI topics in their courses). In contrast, at Spec-S 70% of the 10 respondents taught the code of ethics. This was somewhat unexpected since all had responded to the co-curricular survey invitation. But half taught capstone design and another taught a first-year introductory engineering course; these course types are common sites for ethics education in engineering [30, 31].

Ethical theories were taught to differing extents among the 22 institutions. This topic was taught by a fairly low percentage of the respondents overall (21%). Respondents at the high outlier institution (VH1, 55%) taught the largest number of ESI topics per person on average among the 22 institutions. This may be due to the fact that this institution had the highest percentage of individuals who responded to the curricular survey, and therefore have some experience and/or interest in ESI education in engineering. Notably, this institution was among the five with the highest percentage of respondents teaching all five of the ESI topics that differed by institution. There were three low outlier institutions with no respondents teaching ethical theories (Rel-B; H-B; VH5). At the religious institution, instructors teaching engineering and computing students may believe that students learn about ethical theories from general education classes that are required as part of the university-wide core curriculum that includes philosophy and theology. Similarly, the majority of the respondents from H-B reported that students take a full course on ethics; thus, engineering instructors may not integrate ethical theories into their own courses believing that students receive that training in the full ethics course. Finally, VH5 had the fewest median number of ESI topics taught per person; thus, individuals may simply believe that other ESI topics are more important than theory, instead taking a more applied approach to ethics education for engineering students.

The results imply that particular elements of the culture at an institutional level or within the college of engineering at an institution might encourage or discourage teaching engineering/computing students about SJ, poverty, the societal impacts of technology, ethical theories, and/or ethical codes. Individual, external, or other environmental factors (perhaps at a departmental level or among disciplines) likely determine whether an individual teaches the majority of the ESI topics (e.g. safety, sustainability, environmental protection, responsible conduct of research, ethics in design, ethical failures/disasters, bioethics). The Academic Plan Model [12] acknowledges a wide array of factors that can impact teaching practices. Institutional influences identified in the model include college mission, resources, and governance. External influences like ABET are presumed to be similar across all institutions, but disciplinary associations (an external influence) and unit level influences would vary within and among the institutions. Additional research is needed to determine the relative importance of these many factors.

RQ2. Undergraduate Course Types for ESI Education

Survey respondents were asked where they believed undergraduate students in their program learned about the societal impacts of technology and/or ethics, and were given nine course type options to select or "unsure". Individual respondents identified between 1 and 8 course types with a median of 3; the median among respondents from the 22 institutions ranged from 2 to 4 (Appendix).

Institutional differences were found in the the prevalence that three course types were believed to include ESI instruction: first-year (FY) design, professional issues, and a full course on ethics (Table 3). These settings were not particularly common, averaging 27% or less across all survey respondents. For FY design courses and professional issues courses, it is uncertain if the course is not offered at the institution or is not perceived as a site for ESI education. Further, these courses may be required in some majors and not others. For all of the course settings with higher representation among respondents, statistically significant institutional differences were not found (e.g. capstone design 62%, first-year introductory course 45%, sophomore/junior engineering/engineering science course 38%, sophomore to senior design-focused engineering course 33%, humanities or social science course 32%). Note that the number of individuals identifying the course types for ESI education was sometimes lower than the total number of respondents from the institution, as some respondents checked "unsure" or skipped the question.

Examples of FY design-focused courses that include ESI have been published [31-34]. It may be that individuals less familiar with the curriculum at their institution are unaware that ESI is included in FY design courses, particularly when these courses are taught outside of specific departments by college-wide programs. At Pr-B, a 4-credit general engineering design-focused course in the FY is required for all incoming students and the catalog description indicates that the course topics included ethics in engineering. At H-Pf-S, all incoming students take a required 3-credit FY design course that includes semester-long team projects taught from a human-centered design perspective and including a holistic problem definition phase that includes both cultural and technical perspectives.

Table 3. Institutions with highest and lowest percentage of respondents indicating that ESI education occurred in various course types

Institution	n	Median # course types (range)	% respondents			
			Senior capstone design	FY design-focused course^{+}	Professional issues course (at any level)*	Full course on ethics (any level)*
Pr-B	7	5 (1-7)	71	**57**	**57**	14
H-Pf-S	22	4 (1-8)	68	**55**	5	18
VH5	12	4 (1-7)	67	8	**67**	17
B-L1	14	4.5 (1-8)	50	29	**57**	**57**
H-B	8	3 (2-8)	75	13	***0***	**50**
VH3	12	3 (1-6)	67	33	***0***	25
VH2	13	5 (1-8)	69	38	38	***0***
VH4	10	2 (1-7)	40	***0***	40	***0***
VH7	9	3 (1-5)	78	***0***	33	22

Pearson Chi Test among 22 institutions: $^{+}$ p 0.1 to 0.05; * $p \leq 0.05$, Professional issues courses often include ethics topics [35]. Pr-B required one-credit professional issues courses in each major, which included resolving ethical conflicts among the course topics listed in the catalog. B-L1 includes a two-credit professional issues course in civil, one-credit seminar in mechanical, etc. VH5 included a one-credit ethics and professionalism course in four engineering majors, and larger three-credit professional issues courses in two other engineering disciplines. At VH4, 44% of the engineering degree programs required a 1-credit professional practices seminar course in the junior or senior year where the catalog description included ethics topics (similar to the 40% institutional responses in Table 3); 22% of the degree programs included this type of course but the catalog description did not explicitly mention ethics; 33% of the degree programs did not require a course clearly titled professional issues or similar in the curriculum.

The requirement for a full course focused on ethics appears reasonably uncommon. Sometimes these may be perceived as HSS courses, depending on the specific course that is required. At H-B, engineering students in all majors except civil are required to take a three-credit ethics course with a philosophy prefix; the course satisfies a core curriculum requirement of the university. This was a new requirement being phased-in for students entering in fall 2015. It is unclear if faculty responding to the survey were describing the old or new curriculum requirements, which may have led to differences in the responses. At Institution B-L1, each discipline required a three-credit hour ethics and engineering course that was cross-listed with both an engineering and philosophy prefix.

The respondents from each institution varied to some extent in the number of courses and specific course types that they identified as including ESI. This likely is due to a variety of factors, including differences across majors (e.g. civil, electrical), level of familiarity with the undergraduate curriculum, differences in how individuals teach particular courses within the curriculum, and perhaps even differences in what individuals 'count' as ESI education. These factors might overwhelm differences that are due to institution-level factors.

RQ3. Sufficiency of Students' ESI Education

Survey takers were asked if they felt that the education of undergraduate students in their program on the societal impacts of technology and/or ethics was sufficient (Table 4, Appendix). Faculty perceptions of the sufficiency of undergraduate ethics education in their program differed among institutions ($p=0.011$), ranging from 14% to 90% rating it sufficient (median 40%). Faculty perceptions of the sufficiency of broader impacts education ranged from 20% to 71% of the raters across the 22 institutions (median 45%), and were not statistically different.

The three institutions with the highest sufficiency opinions for undergraduate ethics education were all located in the Plains (Carnegie region 4), so it is unclear if there are regional norms around ethics that might be at work (however, two other institutions located in region 4 had much lower percentages of respondents who felt that the ethics education of undergraduates was sufficient; 44% and 30%). Additional qualitative research could explore the influence of the broader geographic environment on the culture and practice surrounding ESI education, but that was beyond the scope of the current study.

Table 4. Differences in ESI educational sufficiency perceptions among the institutions

Institution	n[+]	Percentage of institutional respondents rating undergraduate education as: sufficient ethics, %	sufficient broader impacts, %
VH7	10	90	70
VH5	8	88	50
Spec-S	10	80	70
Rel-B	8	75	63
H-Pf-S2	8	25	38
H-Pf-S	20	20	20
H-B	7	14	43

[+] n does not include those who noted uncertain or skipped the question

Sufficiency ratings are expected to reflect ethics educational practices at the institution, an individual's knowledge of ESI educational practices in their program, and personal opinions about what comprises sufficient ethics education for engineering and computing students. Ratings of the sufficiency of undergraduate ethics/broader impacts education were weakly correlated with the total number of settings (courses and/or co-curricular) where one believed that undergraduate students in their program learned about ESI (Spearman's rho 0.195, sig. 000, n=1123), but there was not a statistically significant correlation evident among the 300 respondents at the 22 target institutions. Within the entire dataset (n=1149), a higher percentage of the co-curricular respondents rated ESI education as sufficient (53% compared to 32% of the curricular survey respondents). However, at Institution H-Pf-S where only 20% of the 20 respondents felt that undergraduate students in their program received sufficient ethics education, a similarly low percentage of both the curricular and co-curricular respondents felt that their students received sufficient ethics education (22% of the 9 co-curricular survey respondents rated ethics education as sufficient). While the majority of the survey questions related to the quantity of ESI education, this question relates to perceptions of quality. Personal beliefs of what comprises sufficient education likely differ across both topics and level of cognitive and affective outcomes.

RQ4. Institutional Evidence of ESI Support

It was of interest to determine the extent to which institutional artifacts such as the catalog and websites would support faculty's evaluation of the ESI education of their students as sufficient (or not). Only the two institutions where the greatest percentage of faculty rated ethics education as sufficient (VH7 and VH5) and the two institutions where the lowest percentage of faculty rated ethics education as sufficient (H-B and H-Pf-S) were examined.

Institution VH7 had the highest percentage of respondents rating undergraduate ethics and broader impacts education sufficient (90% and 70%, respectively). Among the 11 respondents, 10 responded to the co-curricular survey (responses were received from 34% of the individuals invited to take the co-curricular survey). VH7 is a land-grant institution with typical goals for advancing the well-being of the state, nation, and world in its institutional mission statement. The school website also discussed its land-grant mission in terms of service, and touted being among the first institutions recognized with a Carnegie classification for community engagement. Five student learning outcomes were articulated for all students graduating from the institution which included academic and professional integrity and ethical awareness. General education at the institution level included eight themes that were required for all students, including ethical reasoning and global perspectives. Thus, HSS elective requirements appeared to have ESI dimensions. News on all-university achievements touted ethics education awardees in both the College of Education and College of Engineering. The College of Engineering articulated seven objectives for all students, including one that focused on social issues and another on ethical behavior. Within specific departments, additional evidence of ethical commitment was found among the goals, educational objectives, and required courses. Social context and ethics were particularly prominent in the civil engineering goals and educational objectives. Civil engineering required a 0-credit seminar course every semester that included professional and ethical responsibilities. Ethics were embedded in required FY introduction to civil and mechanical engineering courses. Electrical engineering integrated ethics into 0-credit seminars required in the first two semesters and capstone design. Mechanical engineering capstone design in the final semester also included ethics. Thus, evidence was found that the institution widely supports a culture and environment for ESI educational excellence.

Institution VH5 had the second highest percentage of faculty who rated undergraduate ethics education as sufficient (88%), but a much lower percentage rated broader impacts education as sufficient (50%). All 12 ratings were from co-curricular respondents (60% response rate, higher than overall 18% response rate to co-curricular survey invitations). The institutional mission referred to its land-grant tradition of serving the needs of citizens. Seven core values were listed, which included engagement, contributing to quality of life, and stewardship. In comparison to Institution VH7, ESI-related elements were less prominent. The institution had general education requirements for all students, and one of these outcomes related to ethics and society. This requirement could be fulfilled by selecting from among a list of courses. Individual engineering majors included additional ethics-related content. For example, civil engineering included ethics in a 3-credit professional practice course in the junior year. Construction engineering integrated societal and ethical issues in a 3-credit engineering economics course in the sophomore year, plus an entire 3-credit course on accident prevention in the senior year. One of the five learning objectives in electrical engineering integrated sustainability and human interactions. Comparing Institution VH5 to Institution VH7, the lower sufficiency ratings for broader impacts seem consistent with the institutional environment.

Institution H-B had the lowest percentage of respondents who rated ethics education as sufficient (14%), but an average percentage rated broader impacts education as sufficient (43%), representing a large differential in favor of broader impacts. All nine of the responses representing Institution H-B were from the co-curricular survey (response rate 50%). The median of three course types including ESI reported by faculty at the institution was on the low side among the 22 institutions. Institution H-B did not articulate a vision with specific ethics or service elements, focusing more generally on student success and preparation for lifelong learning. Institution H-B adopted core curriculum for all undergraduate students in fall 2015 (just prior to the survey administration in spring 2016). The core curriculum required seven learning outcomes, one of which was social responsibility and ethics. Engineering students took an ethics-related course from philosophy to fulfill this requirement. The college of engineering did not have a stated mission or objectives directly relevant to ESI. The introduction to engineering courses required in the first-year appeared to have a technical focus; ethics was not evident in the course descriptions in the catalog. The capstone design course descriptions in the catalog for all of the engineering majors also did not mention ethics. Two of the seven engineering BS degrees included ‘ethics’ among the program objectives; one of these majors also stated on its website that it emphasized safety and ethics. Perhaps the engineering faculty were largely dissatisfied with the ‘outsourced’ approach to ethics education, believing it insufficient for engineering students. This institution had integrated service-learning into many courses, which the survey respondents may have perceived as beneficial to ‘broader impacts’ education. In comparison to Institutions VH-7 and VH-5, there was less focus on ESI found among the documents pertaining to Institution H-B.

Institution H-Pf-S had the second lowest percentage of respondents who rated undergraduate ethics education as sufficient (20%) and the lowest percentage rating broader impacts education as sufficient (20%). Among the 24 survey responses, 46% were co-curricular (response rate 48%). However, the low sufficiency ratings may be reflective of faculty respondents having particularly high standards for sufficiency. For example, this institution had the highest percentage of the survey respondents who taught societal impacts (70%) and second highest percentage who taught social justice and poverty issues (50% and 42%, respectively); see Appendix for comparisons to the percentage of faculty at the other institutions teaching these topics. The institution mission, vision, and values all promoted working toward a ‘better world’ and included aspirations toward sustainability as well as discussing social and environmental systems. Ethical behavior was specifically included among three vision statements and listed among five attributes for all graduates from the institution. Engineering was the focus of the institution (clear from the “professions” Carnegie classification). The core curriculum at the institution applied to all students and included a required first-year design course that integrated ethics and a four-credit HSS course that integrated ethics. Four of the engineering majors included ethics in their program educational objectives. A number of the capstone design course descriptions in the catalog included ethics, as well as additional technical engineering courses in some majors integrating ESI topics. Overall, the institutional artifacts reflected a strong culture of ESI education in engineering, similar to Institution VH7. Perhaps the faculty at the institution were somewhat bifurcated – some pushing for more ESI, including an ESI across curriculum attempt, and others more traditionally focused. It could be postulated that those who responded to the survey represented those with high aspirations for the ESI education of undergraduate engineering students.

Limitations and Future Work

This research primarily explored mathematical differences among survey responses from individuals at institutions with the largest numbers of respondents. No engineering programs at liberal arts focused colleges were among those with a high number of respondents; the findings among the 22 institutions should not be generalized more broadly. It is unknown to what extent the individuals who responded to the survey were fully knowledgeable about the ESI content of the curriculum in their program, were representative of faculty who teach ESI to engineering and computing students at the institution, or were representative of engineering faculty at the institution more generally. We believe that it is likely that individuals who responded to the survey were more interested in ESI than typical engineering faculty members, in alignment with leverage-salience theory and the work of Groves et al. [36]. These individuals may have more knowledge of ESI content in the curriculum of their program and may also hold higher standards for ESI sufficiency. Therefore, this research is unable to draw definite conclusions about institution-level effects on the ESI education of engineering/computing students. However, this preliminary study raises a number of interesting questions for future in-depth research.

In on-going work, 37 faculty members were interviewed to gain more insights into their teaching practices and institutional culture. Some of these individuals described their institutional cultures as being supportive, and others as unsupportive [13]. However, when asked about institutional culture, interviewees tended to focus on department instead of the broader environment, and discussed how it was more influential because of its role in promotion/tenure, curriculum development, course approval, and faculty culture. The interview results imply that the department-level culture is more important than the broader environment of the College of Engineering or institution at large (unpublished data). A case-study approach is being taken to explore the role of institution-level impacts relative to other environmental effects.

Summary

This research explored whether institution-level differences were evident in the ESI teaching practices and perceptions of faculty who educate engineering and computing students. There were 22 institutions where ESI educational practices in engineering were compared based on survey findings. The research identified only a few ESI topics that differed across institutions in the extent they were taught by individuals who educate engineering and/or computing students, including social justice, engineering and poverty, societal impacts of technology, code of ethics, and ethical theories. The other 13 ESI topics did not differ across institutions in the percentage of survey respondents who integrated them into their courses. Further research is needed to untangle the extent to which personal, external, department level, and institutional factors in Lattuca and Stark's Academic Plan Model [12] influence educators' decisions to teach particular ESI topics. ESI integration did not differ across institutions in most types of undergraduate courses (e.g. capstone design, first-year introductory courses). Exceptions were first-year design courses, professional issues courses, and full courses on ethics. It is likely that these course types are not required at some institutions (e.g. professional issues-focused course). The percentage of individuals who teach ESI to engineering and computing students and rated the ethics education of students in their program as sufficient varied among institutions – from nearly complete agreement of sufficiency to nearly complete agreement that ethics education was insufficient. Characteristics at the institution (e.g. mission, core curriculum requirements for all students) and college of engineering (e.g. objectives, first-year program) appeared to generally support extreme differences in sufficiency ratings. However, the results also demonstrated the limitations of this survey-based research with respect to understanding ESI educational practices and perceptions in engineering and opportunities for future work.

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Appendix.

Survey Question: Do you teach engineering and/or computing students about any of the following topics in any of your undergraduate and/or graduate courses? (check all that apply)

- Bioethics
- Engineering code of ethics (e.g. NSPE)
- Engineering decisions in the face of uncertainty
- Engineering and poverty
- Environmental protection issues
- Ethical failures/disasters
- Ethical theories
- Ethics in design projects
- Nanotechnology ethics
- Privacy and civil liberties
- Professional practice issues
- Responsible conduct of research
- Risk and liabilities
- Safety
- Social Justice
- Societal impacts of engineering and technology
- Sustainability and/or sustainable development
- War, peace, and/or military applications of engineering
- Other topic(s) related to social and ethical issues (identify)
- No topics related to the societal impacts of technology or ethics

Survey Question: Where do you think undergraduate students in your program learn about the societal impacts of technology and/or ethical issues? [check all that apply]

- A first-year introductory course;
- A first-year design-focused course;
- Sophomore or junior level engineering science and/or engineering courses;
- Design-focused course in sophomore, junior, or senior year;
- Humanities and/or social science courses;
- Full course on engineering ethics (any level);
- Senior capstone design;
- Professional issues course (at any level);
- Co-curricular engineering service society (e.g. Engineers Without Borders);
- Co-curricular engineering professional society (e.g. AIAA, AIChE, ASCE, ASME, IEEE);
- Other courses and/or co-curricular activities (please explain below);
- Unsure.

ESI Topics Taught and Program Course Types and Sufficiency Perceptions

Institution	% sufficient ethics*	% sufficient broader impacts	Median # Course Types	% FY dsn crs$^+$	% prof issues crs*	% full ethic crs*	Med. # ESI topics	% teaching ESI topic: Societal impacts	Code of ethics	Eth theory	SJ **	Eng & poverty *	% Cocur survey
ALL	42	43	3	20	27	18	5	50	42	21	17	15	73
VH7	**90**	**70**	***2***	***0***	33	22	4	***9***	***18***	9	18	9	91
VH5	**88**	50	**3.5**	***8***	**67**	17	***2***	***17***	***17***	***0***	8	***0***	**100**
Spec-S	**80**	**70**	3	11	22	11	3	40	**70**	10	10	10	**100**
Rel-B	75	63	3	25	13	25	4	56	22	***0***	***0***	11	67
VH-B	55	36	3	27	27	18	***2***	31	31	15	15	***0***	***38***
VH3	50	60	3	33	***0***	25	3.5	50	25	17	8	***0***	64
B-L1	50	44	**4**	29	**57**	**57**	5	47	53	**33**	13	7	82
PrL-B	50	50	***2***	20	***0***	20	5.5	63	38	13	**63**	**38**	78
VH4	44	44	***2***	***0***	40	***0***	**6**	**64**	***0***	9	**36**	**46**	85
H-S	44	50	2.5	25	38	13	5	50	39	17	***0***	11	68
Pr-B	43	**71**	**4**	**57**	**57**	14	4	**64**	55	27	9	9	73
B-L2	36	29	***2***	20	20	10	5	43	36	29	21	29	60
MS	33	***25***	3	18	18	9	**6**	58	**58**	17	8	8	58
VH-L	33	39	***2***	33	24	5	5	43	52	29	5	19	62
B-L3	33	33	***2***	11	22	**33**	4	36	55	18	9	9	64
Pr-H-S	30	60	3	22	33	11	4	**64**	27	9	18	7	82
VH6	30	40	***2***	11	11	11	3	27	27	9	***0***	9	83
VH2	27	***27***	3	38	38	***0***	4	***20***	27	13	7	7	53
VH1	27	33	3	**47**	**47**	13	**7**	**65**	**60**	**55**	20	20	***35***
H-Pf-S2	25	38	**3.5**	25	38	***0***	**6**	36	36	27	***0***	9	45
H-Pf-S	***20***	***20***	3	**55**	5	18	**6**	**71**	33	21	**50**	**42**	46
H-B	***14***	43	3	13	***0***	**50**	4	50	38	***0***	13	***0***	**100**

$^+$ p 0.1-0.05; * $p \le 0.05$; bold are highest values among institutions, bold italics are lowest values among institutions

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