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Performance of Engineering Faculty on the Engineering and Science Issues Test (ESIT)

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Introduction

Concern for teaching ethics in the engineering profession has persisted for many decades. As early as the 1940s, engineering as a professional discipline has articulated a focus on public health, safety, and welfare. This focus is codified in the ethical responsibilities of engineering professional associations including the Institute of Electrical and Electronics Engineers (IEEE) and the National Society of Professional Engineers (NSPE). Beyond professional associations, the Accreditation Board for Engineering and Technology (ABET) has also adopted ethical responsibility as a necessary component of curricula at accredited institutions [1]. Over time, these trends have increased research focused on the teaching of ethics in engineering education [2] and the system of teaching engineering ethics [3]. The research focused on teaching of ethics often explores which instructional practices foster ethical reasoning and decision making; reporting on the development of an intervention, evaluating student performance on ethics related course work, and/or comparing student pre/post course performance on ethical reasoning tests. A few (but not exhaustive) list of examples includes: Berne and Schummer investigated the use of discussion prompts to engage students in a discussion of the ethical implications of nanotechnologies featured in selected science fiction publication [4], Bevilacqua investigated having students analyze outlandish case studies from movies and television shows[5], Brummel et al. investigated role-play scenarios to teach students how to conduct responsible research [6], Luo et al. investigated the change in ethical judgment and awareness of graduate students at a Chinese institution after a course on scientific ethics and academic integrity [7], and Rockwell and Zhu investigated the relationships between ethical reasoning, level of education, and institution among engineering students in China [8]. There is less attention given to how to teach ethics to engineering faculty (who may have had little ethical training themselves prior to their professional practice) or how engineering faculty perform on ethical reasoning tests. The latter could be an important consideration when understanding the education environment that students are receiving their ethical education.

This motivates the guiding questions for this work, which are: **RQ1)** Do engineering faculty who report teaching ethics topics in their courses perform better on a test of moral judgment than their peers who do not teach ethics topics? and **RQ2)** Do engineering faculty perform better on a test of moral judgment than undergraduate engineering students?

To answer these research questions, engineering faculty at the University of Alabama were surveyed and asked to complete the Engineering and Science Issues Test along with questions about their teaching of engineering ethics topics and their own engineering ethics education. This collected data was utilized to answer RQ1 and its comparison to published data in the literature was used to answer RQ2. The following sections provide an overview of the instrument used in this study, the data collection methods, data reporting/analysis, and a discussion of the results in the context of existing work in engineering ethics education.

Engineering and Science Issues Test (ESIT)

The Engineering and Science Issues Test (ESIT) is an instrument developed by Borenstein et. al for the measurement of moral judgment tailored to technical dilemmas [9]. This test presents six dilemmas (or cases) with ethically problematic situations a scientist or engineering might reasonably expect to confront in practice. For each dilemma, respondents are asked to review it, make a decision about the case, then rate and rank a series of 12 questions in terms of how important they are to the dilemmas. The questions for each case present different ways to judge what is important for decision making. Each question falls into one of four perspectives, referred to as pre-conventional, conventional, post-conventional, and nonsensical. Questions from the pre-conventional perspective center concerns/judgments on oneself, conventional perspectives center concerns for social conventions and laws, and post-conventional center concerns on universal principles of justice. The nonsensical answers are included to identify respondents who are not taking the test seriously. The ratings and rankings are used to generate two scores of moral judgment, referred to as a P-score and N2-score. The P-score is to determine the degree to which post-conventional thinking is prevalent while the N2-score is to determine the degree to which the post-conventional thinking is prevalent AND pre-conventional thinking is absent.

Methods

To answer the motivating study questions, an online survey request was distributed to 154 faculty in the College of Engineering at the University of Alabama. Interested faculty were asked to complete the ESIT, report their home department, rank (assistant professor, associate professor, professor), if they taught engineering ethics in any of their courses, and if they received any ethics training as part of their engineering education. All faculty who completed the survey were paid \$30 to incentivize completing it. With this recruitment approach 52 faculty completed the survey, yielding a response rate of 33.8%. After review of responses 14 were discarded because of omitting too many questions to be considered reliable (e.g. failing to complete rating or rankings equivalent to two dilemmas) or were too nonsensical (e.g. highly ranked nonsensical options for dilemmas); both based on the recommendations of Borestein et. al for removing data [9]. Therefore, 38 responses were analyzed for this study (representing 25% of the total group contacted).

From the provided answers the P-score and N2-score were calculated using the key and method provided by Borenstein et. al [9]. As a summary:

- **P-Score:** For each dilemma, the number of post-conventional points were determined by assigning a score of 4 to any post-conventional response ranked as most important, 3 for those ranked as second most important, 2 for third most important, 1 for fourth most important, and 0 otherwise. Then a total score was generated by summing the scores for all

Rank	Responses
Assistant	17
Associate	10
Professor	7
Not Provided	4
Total	38

Table 1: Distribution of faculty survey respondents by institutional rank.

Department	Responses
Aerospace Engineering and Mechanics (AEM)	3
Mechanical Engineering (ME)	7
Metallurgical and Materials Engineering (MTE)	3
Chemical and Biological Engineering (ChBE)	7
Civil, Construction and Environmental Engineering (CCEE)	7
Computer Science (CS)	3
Electrical and Computer Engineering (ECE)	4
Not Provided	4
Total	38

Table 2: Distribution of faculty survey respondents by department.

six dilemmas. Finally, the P-score was generated by dividing the total score by the total available (60). This total was adjusted for any omissions of dilemma rankings (removing those points from the denominator).

- **N2-Score:** The average rating (1-5) of all post-conventional issues (μ_{POST}) and all pre-conventional issues (μ_{PRE}) was calculated. Next, the standard deviation of ratings of all post-conventional and pre-conventional issues grouped together ($\sigma_{\mathrm{POST,PRE}}$) was calculated. Finally, the N2-Score was generated as:

$$\mathrm{N2} = \mathrm{P} - 3 \cdot \frac{\mu_{\mathrm{PRE}} - \mu_{\mathrm{POST}}}{\sigma_{\mathrm{POST,PRE}}} \tag{1}$$

  where P is the previously calculated P-score (as a value between 0 and 1).

Responses from faculty were grouped based on their response to the question: *In the courses you teach, are ethical considerations for scientists/engineers considered or discussed as part of the curriculum?* Faculty who responded yes were grouped and are referred to as 'Ethics Teaching' in this work, while faculty who responded no (or did not respond) were grouped and referred to as 'No Ethics Teaching' in this work.

The statistical testing in this study was completing using SPSS Statistics v29 (IBM Corp., New York). The goal of this testing was to evaluate if there were group differences in P-scores and N2-scores between the two faculty groups (those who teach ethics topics in their engineering classes and those who do not). The specific statistical test used to evaluate this was the independent samples t-test.

Group	P-Score	N2-Score
Ethics Teaching (20)	0.422 (±0.132)	2.134 (±1.230)
No Ethics Teaching (18)	0.398 (±0.083)	1.576 (±1.179)

Table 3: P-Scores and N2-Scores for engineering faculty grouped by ethics teaching

Results

The set of faculty who participated in this study were primarily at the rank of Assistant Professor (representing 54% of participants), with faculty at the rank of Associate Professor representing 26%, and faculty at the rank of Professor representing 18%. The specific number of participants at teach rank are summarized in Table 1. Responses were received from all 7 departments in the College of Engineering at the University of Alabama, with the number of responses per department given in Table 2. A total of 20 faculty self-reported that they teach ethics concepts in one or more of their classes (53%) and 18 faculty reported they did not teach ethics explicitly or did not answer the question (47%). Further, only 15 (39%) of these faculty reported having ethical considerations for scientists and engineers in their own engineering education, 4 reported limited considerations, 4 reported no consideration whatsoever, and 11 did not provide a response to this question.

Using the methods previously described, the average P-score and N2-score from the ESIT data for both groups of faculty are given in Table 3. Faculty who reported teaching ethics concepts in their courses had scores (mean $\pm$ standard deviation) of 0.422 ± 0.132 and 2.134 ± 1.23 for P and N2, respectively. While those faculty who reported not teaching ethics concepts in their courses had mean P2 and N2 of 0.398 ± 0.083 and 1.576 ± 1.179, respectively. For both scores, the group of faculty who self-reported teaching ethics in their courses have higher values. From the independent samples t-test the mean differences between P-scores (0.241) and N2-scores (0.558) were not statistically significantly different ($p > 0.05$) with effect sizes of 0.215 (low) and 0.463 (moderate), respectively, indicating that there was no difference in ethical reasoning performance on the ESIT based on group. Note that effect sizes here were calculated using Cohen's proposed method [10].

For further insight into how engineering faculty answered the ESIT questions, the summarized ranking data for each of the six dilemmas grouped by schema are given in Table 4. Recall that for each dilemma, participants were asked to rank the 4 items they felt were most important. Reviewing the data for Case 1, the majority of faculty (20 of 38 or 53%) ranked conventional items as the most important (Rank 1) with post-conventional items selected with the next highest frequency (37%). Overall, the majority of faculty selected post-conventional items as the most important for only 2 ESIT cases: Case 3 (Contracts) and Case 6 (Product). Conventional issues were the top-ranked in 2 cases: Case 2 (Leaks) and Case 5 (Technology). While the remaining cases, Case 1 (Stock) ad Case 4 (Testing) are split between post-conventional and conventional schemas.

ESIT Case	Rank 1	Rank 2	Rank 3	Rank 4
Case 1 (Stock):				
Post-Conventional	14	18	12	21
Pre-Conventional	3	1	5	7
Conventional	20	16	16	9
Nonsensical	1	3	5	0
Not Answered	0	0	0	1
Case 2 (Leak):				
Post-Conventional	8	20	21	15
Pre-Conventional	5	10	6	8
Conventional	24	8	10	15
Nonsensical	1	0	0	0
Not Answered	0	0	1	0
Case 3 (Contract):				
Post-Conventional	22	15	12	11
Pre-Conventional	8	8	11	11
Conventional	7	15	13	13
Nonsensical	1	0	2	3
Not Answered	0	0	0	0
Case 4 (Testing):				
Post-Conventional	14	15	15	20
Pre-Conventional	7	6	4	7
Conventional	15	17	18	11
Nonsensical	2	0	1	0
Not Answered	0	0	0	0
Case 5 (Technology):				
Post-Conventional	4	8	7	16
Pre-Conventional	8	7	17	6
Conventional	25	22	12	14
Not Answered	1	1	2	2
Case 6 (Product):				
Post-Conventional	26	19	22	8
Pre-Conventional	2	4	5	6
Conventional	8	12	5	6
Nonsensical	0	1	0	5
Not Answered	2	2	2	2

Table 4: Distribution of faculty rankings grouped by answer-type

Discussion

While the mean P-scores and N2-scores of the engineering faculty who teach ethics in their courses were higher than their counterparts who did not teach ethics in their courses, the differences were not statistically significantly different. This does not align with the initial study expectations, which were that faculty who teach engineering ethics topics were expected to score higher in ethical reasoning. One potential reason for this could be that even when faculty teaching ethics topics the specific perspectives they present may fall into the conventional category (e.g. center concerns for social conventions and laws) and not post-conventional (e.g. center concerns on universal principles of justice). To explore this further, a deeper reading of faculty answers to the survey question: *In the courses you teach, are ethical considerations for scientists/engineers considered or discussed as part of the curriculum? If yes, describe how. If no, are there specific reasons that these topics are not considered that you can comment on?* was completed. From this review, the emergent theme is that this group of faculty introduces ethical concepts from perspectives related to contracts, laws, standards, and professional integrity. While a few references are made to concerns for the public and public safety (which most closely aligns with post-conventional perspectives), they are not the dominant perspective. This supports that these faculty teaching ethics are presenting conventional perspectives which is likely to align with their own perspectives. But it is also important to highlight that this self-reported set of topics is limited and that faculty may in fact introduce more post-conventional perspectives than indicated here (and would be an interesting site for future research).

While there were no studies identified in our literature search that evaluated faculty ethical reasoning using the ESIT, there are previous studies that have used this instrument in student populations. A short summary of these studies, the measured population, and scores (where available) are below:

- Borenstein et al. measured 425 students (predominantly engineering undergraduates at the junior and senior levels) with ethics training and 25 students without ethics training. The group with prior ethics experiences had mean a P-score of 0.523 and N2-score of 3.326. The group without ethics experience had a mean P-score 0.489 and N2-score of of 2.632 [9].

- Freeborn et al. measured first-year undergraduate engineers reporting details of two groups of electrical and computer engineering students participating in a first-year course designed to integrate ethics topics using either a problem-based learning (PBL) or lecture-based (LB) style and a control group of undergraduate first year engineers across disciplines (except electrical and computer engineering). They reported N2 scores of 1.89, 2.08, and 1.83 the LB group (55 students), PBL group (53 students), and control group (217 students), respectively [11].

- Selby measured two groups, one with (mostly) first-year undergraduate engineering students and senior undergraduate engineering students. They reported P-scores of 0.516 and N2-scores of 2.508 for the first-year students in an introductory course (63 students) and P-scores of 0.487 and N2-scores of 2.636 for senior seminar students (81 students) [12].

- Fiegel et al. measured two groups of students, first and second year undergraduate engineering students who did and did not participate in a ethics training intervention. They reported post-intervention P-scores of 0.566 and N2-scores of 0.589 for the experimental group (58 students) and P-scores of 0.544 and N2 of 0.572 for the control (83 students) [13].

- Schell measured undergraduate industrial engineering students after participating in a course to improve ethical decision making [14]. From data reported by Schell the mean P-scores and N2-scores from 20 students were calculated as 0.460 and 3.458, respectively.

It is interesting to note that the faculty in this study have lower average P-scores than the student groups in the reported studies. Similarly, the faculty with no ethics teaching have the lowest average N2-score of all reported groups, while those with ethics teaching only have higher a N2-score than that undergraduate engineering freshman scores reported by Freeborn et. al [11]. While further comparison is needed to evaluate the statistical significance of these differences, this may indicate that the participating engineering faculty received even less ethics training in their engineering education and professional development than undergraduate students receive in the last decade. This is further supported in the faculty responses to the survey question: *Considering your own engineering education, were ethical considerations for scientists/engineers considered or discussed as part of the curriculum? If yes, describe your experiences with these topics and how they were introduced to you during your education.* The responses to this question suggest that faculty who did receive ethics training (which was only 39% of participants) had it focused on case studies, safety, failure analysis with few references to social responsibility or post-conventional perspectives. If most faculty received little ethical reasoning / decision making training, and the training they did receive was primarily from a conventional perspective, it is not unsurprising that the reported faculty scores are similar or lower than current undergraduate students.

An interesting question builds from this: Is it possible for undergraduate engineering students to move towards post-conventional ethical decision making in an educational environment where conventional approaches to ethics are dominant? Work by Cech suggests that this answer is no and that "students' experiences over the course of their undergraduate programs decreases their interest in the public welfare considerations of engineering work" [15] based on their sampling of 326 students who entered engineering programs at multiple institutions in 2003 and were followed until their graduation. The findings of this work, that engineering faculty ethical decision making aligns most often with conventional perspectives, could be part of the reason for the culture of disengagement reported by Cech [15]. Though this needs to be further studied across institutions and with a greater number of faculty to determine if this is generalizable.

Overall this introduces other sites of future research to address questions including: What training interventions can increase engineering faculties post-conventional decision making for ethical dilemmas? And if engineering faculty across a department or institution have increases in post-conventional perspectives are these increases mirrored in engineering student populations? The faculty responses in this study could help guide initial explorations on these topics. Recall that conventional issues were top-ranked in 2 of the ESIT cases by faculty in this study. One of these cases focused on what to do regarding findings of leaking industrial lubricants into groundwater and the other focused on disclosing proprietary information. Further investigation into how engineering faculty reasoned through these cases and why they selected the conventional items as most important could provide insight into how to design an intervention to improve post-conventional reasoning for these and similar topics.

Conclusion

In this study, a group of 38 engineering faculty from the University of Alabama completed an online version of the ESIT, an instrument for the measurement of moral judgment tailored to technical dilemmas. The faculty responses were grouped based on their self-reported teaching of ethical topics in their engineering courses. From two scores calculated from the ESIT responses (e.g. P-score, N2-score), there was not a statistically significant difference between the average scores of both groups. Based on a review of the faculty responses regarding how ethics topics are taught in their courses, this limited difference could be attributed to conventional ethics perspectives (e.g. centering concerns for social conventions and laws) being prevalent.

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