Incorporating Ethics and Social Responsibility in Undergraduate Engineering Education

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Abstract - **One tactic that has not been effectively evaluated to increase the numbers and the involvement of women and underrepresented minorities in engineering is the incorporation of a socially and ethically relevant framework in the teaching of engineering at the undergraduate level. In this research, we are characterizing the efforts currently utilized in universities to integrate social relevance and engineering in the curriculum. We are conducting a pilot study to evaluate the effects of these efforts on overall student interest in the field and retention, women and minority student interest and retention, and students' awareness of the overlap between society and technology. This study involves a pre- and post-semester survey of students in engineering courses that incorporate ethics and social responsibility to a greater or lesser degree. We plan to make suggestions for the most effective strategies currently used and to recommend new strategies to incorporate these issues in the engineering curriculum, with a focus on the attitudes of women and underrepresented minorities.**

Index Terms - diversity, engineering ethics, evaluation of ethical curricula, social responsibility.

INTRODUCTION

There has been much discussion in recent years about expanding the ethical training of engineers, and numerous departments focused on the intersection of technology and society have developed in response. Within some engineering departments themselves, a greater emphasis on the incorporation of social elements of technology into technical coursework has been encouraged by the Accreditation Board on Engineering and Technology [1]. The long-term goal of our proposed research is to determine whether the incorporation of ethical and social issues into the engineering curricula affects the way engineering is both practiced in the outside world and/or attracts students from underrepresented populations. Though one goal of the current research is to determine whether the number of women and underrepresented minorities interested in or remaining in engineering increases when issues of ethics and social justice are incorporated in the curriculum, we urge that the sheer increase of students in these groups is not the only goal of this research. Ultimately, we hope that by increasing the representation of any students who value social responsibility, engineering itself will become a more socially-aware field.

BACKGROUND

Our assertion is that underrepresented minorities and women may be drawn to an engineering curriculum that integrates social and ethical dimensions of engineering. There is evidence to suggest that, in general, women and underrepresented minorities are more likely to pursue careers that emphasize helping others and social concern [2, 3]. Elaine Seymour attributes this difference in career motivation to varying socialization of boys and girls in Western society [3]. Based on this precedent, we have reason to believe that by incorporating such elements, attraction and retention of females and underrepresented minorities to engineering could improve.

Attempts to incorporate ethical or social dimensions into the science and engineering curriculum are abundant, but few of these attempts have shown clear data that supports their effectiveness in terms of student retention overall, attraction and retention of underrepresented minorities, and the way students view their career choices. Examples of courses and curricular methods to incorporate ethical and social dimensions include the following:

(a) A thermodynamics course at Cornell University focuses on the workings of the combustion engine. Within the system of study, atmospheric effects are also incorporated [4].

(b) A thermodynamics course at Smith College is taught using a "Pedagogies of Liberation" technique. Briefly, this teaching style emphasizes a cooperative approach to learning, rather than a more traditional top-down approach. The students are encouraged to teach one another, to relate thermodynamics to their everyday lives, and to complete an ethics group problem in the course. At the heart of this pedagogy is an examining and questioning of corporate or military values, thus placing engineering within a social construct. An example of a topic discussed in class is non-Western thermodynamic technologies [5].

(c) A thermodynamics, separations, and material balance course at Worcester Polytechnic University introduces culturally and globally- sensitive material along with technical information. Topics include global energy distribution and consumption and power plant design and construction in Southeast Asia [6].

(d) Some of the engineering departments at Texas A&M require a formal engineering ethics course of all graduating engineers. This course is co-listed by Philosophy and Engineering Departments and is largely taught by a philosophy professor [7].

(e) The Electrical and Computer Engineering Department at the University of Puerto Rico at Mayaguez incorporates an ethics module within the capstone design courses. This module addresses issues such as: the difference between ethics, law, and morality; the need for and characteristics of professional integrity as an engineer, and a brief discussion of ethical frameworks. Case studies relevant to the technical course material are presented; for example, in "Communication System Design," a case study about the health impact of high power radio transmission towers was considered. Overall, UPRM utilizes an Ethics Across the Curriculum strategy, which emphasizes integrating ethics exercises and modules within engineering courses rather than as a stand-alone ethics course [8].

Engineering professors interested in incorporating social, ethical, and global issues in their classes often do not have the time, training, or resources to effectively evaluate the effectiveness of these efforts. There are, however, a few researchers who have attempted to analyze these efforts. DiBiasio, et. al., who implemented example (c) above, found in his course that while the students' understanding of cultural issues related to engineering improved, their integration of these considerations during calculation-intensive activities was inconsistent. The inclusion of cultural and global topics did not impede student learning of the technical concepts, however. Females were more likely than males to incorporate ethical and social considerations within their engineering coursework both in the short and long-term, which again supports our hypothesis that women may be more attracted to engineering if social relevance were consistently emphasized [6].

Drake, et. al. evaluated the impacts of two different types of ethical interventions in the classroom [9]: a full semester ethics course versus an engineering course with an ethics module. No statistically significant difference in moral reasoning abilities between students in the two courses was found, utilizing the Defining Issues Test (DIT). The DIT is a popular measure of ethical and moral reasoning and is based on Kohlberg's cognitive theory of moral development. The researchers also concluded that there was no gender difference in moral reasoning abilities.

Old. et. al. evaluated the impact of the Connections Program at the Colorado School of Mines on graduation rates. This first-year program integrated coursework in the humanities, social sciences, physical sciences, and engineering. The researchers found that those who participated in the program displayed a higher graduation rate (84%) after five years versus those who did not (61%) [10]. Such data provides support for the hypothesis that integrating social and technical issues increases student interest and retention in engineering.

We have expanded on this prior research by developing a new analytical survey tool to gauge the effectiveness of ethical interventions in the classroom. Though techniques such as the DIT have proven effective in a number of educational settings, because it tracks broad stages of moral development, it has not illustrated sensitivity to developmental changes over a short time frame. This lack of sensitivity could be due to the design of the evaluation scheme, or it could imply that such development does not occur over the short term. As this study took place over the course of a semester, a different tool was required. Furthermore, because we were concerned with ethical and social issues that are particularly relevant to engineering-specific situations, an entirely new tool for ethical reasoning that emphasizes case studies and situations in engineering was needed. The work presented here is also novel because we have applied this new survey tool to a greater variety of ethical curricular approaches than has been done in previous research. The survey was conducted using student respondents from nine different universities in a total of 16 separate classes.

METHODS

I. Current Ethics Efforts in Undergraduate Courses or Curricula

The first portion of this research involves categorizing efforts currently undertaken to introduce ethics and social responsibility into the undergraduate curriculum, and specific examples of current efforts were discussed in the previous section. We will generalize the types of ethical and social interventions undertaken by engineering departments after exploring numerous specific examples here. Some engineering departments choose to largely keep the ethical/social component separate from the technical component through separate courses or distribution requirements. Some schools choose to introduce short ethics modules that take up one or two course periods in a single class that is otherwise purely technical in nature. Other efforts may include introducing socially relevant technical problems within individual classes (for example, by incorporating the environment at large in models used to evaluate the products of a chemical reactor or an engine) [4]. Still others may choose to change the way engineering is traditionally taught altogether and have ethical and social issues inherently imbedded throughout the curriculum, rather than simply in individual courses. One could conceive of these as four different methods of introducing ethics or social responsibility within the engineering curriculum. We argue that, from more to less "integrative," these methods would be: (I) separate humanities and technical courses, (II) ethics modules in one or two technical courses, (III) interdisciplinary courses integrating technical and ethical/socially-relevant material, and (IV) entire curricula that integrates technical and ethical/socially-relevant material. We hope to group results from our survey loosely by these categories. We have also developed a rubric that "ranks" the ethical/social treatment in the courses we have studied based on course content and pedagogy. Because many of the courses we included in this study fell in Category III (which is perhaps the most common method of the four), this rubric helps delineate the differences between the courses in this study more effectively. This rubric will be discussed in detail in the following section.

II. Survey Development and Discussion

The broad concept of "effects" of this ethical coursework can be broken into a variety of different questions:

- What impact does such coursework have on enrollment numbers in technical disciplines, in general, and those from underrepresented minorities, in particular?
- Do we retain those from diverse backgrounds in the field?
- Does it impact how engineering students view their career choices?
- Do certain tactics to incorporate these issues into coursework work better than others?
- Do students show increased sensitivity and awareness to ethical and social issues in engineering after exposure to this coursework?
- Is there a correlation between a student's general social involvement and awareness (i.e. volunteerism, social engagement) and their awareness of engineering-specific social or ethical problems?

Our study attempts to address these issues using a survey technique. The survey we have developed serves as an analytical tool to evaluate students' ethical sensitivity, generally, and in an engineering context, specifically. This survey also gauges whether the students' desires to remain in the engineering field have changed as a result of the introduction to social responsibility in engineering through their coursework.

The survey consists of four primary question sections: (I) demographic data, (II) general interest in social issues, (III) specific awareness of ethical and social issues in an engineering context, and (IV) students' reasons for selecting engineering as a field. Some questions in Part II were based on work done by Schwartz in his work on human values, wherein he concluded that asking people to rank the importance of seven major values serves as a good indicator of social awareness and action [11]. In this section, in addition to "values" questions, we also asked specific "action" questions about the students' social involvement (through volunteerism, donating blood, etc.) A brief case study in Part III was adapted from the Online Ethics Center [12]. Otherwise, Part III consists of novel engineering-specific questions related to ethical and social issues. Part IV asks students to select important factors in their decisions to become and remain engineering majors and, perhaps, professional engineers. The survey was administered in a "pre-" and "post-" test fashion during the winter/spring semester of 2007, in order to evaluate the impact of the class on student attitudes and ethical awareness. The "pre-test" survey was administered with responses received within three weeks of the first day of class, and the post-test was administered within the last two weeks of classes. The 850 students invited to participate in the study attend one of nine universities. Four universities are major public institutions, and five colleges are smaller private schools. Some surveys were administered via pen and paper, but most surveys were administered online. All the post-tests were administered online. For the pre-test administration, about 200 responses were received. We anticipate between 115 and 175 responses to the post-survey. Students who complete both sections will be entered into a lottery for one of two I-Pod Nanos.

Because some of the courses we investigated had small numbers of respondents, to obtain statistically valuable information from the study, we grouped the courses into different categories. The rubric we developed to assist in this categorization evaluates the courses in three primary areas: content, pedagogy, and total time devoted to ethical or socially-relevant material. Each course was ranked on a scale of 1 to 5 in each of these categories. The content category ranks the course's overall innovation in linking the technical material with its social relevance. The more integrated the material, the higher the value that was assigned to the course. The pedagogy category examines how the course material is delivered and assessed; for example, the class may be purely lecture-based, or it may include in-class group work and discussion, etc. A more student-centered or sophisticated pedagogy would elicit higher rankings. Finally, the overall time spent on discussion of socially or ethically-relevant issues in the classroom was considered.

We anticipate that all data taken during this semester will be analyzed and ready for presentation in time for ICEE 2007. We are using the statistics package SPSS to evaluate the impacts of different course types on students' ethical reasoning skills, the effects of such course material on students' interests in remaining engineers, and any differing impacts on women and underrepresented minorities. The survey will also allow us to comment on whether the overall social engagement of students will impact their response to this coursework.

CONCLUSIONS AND FUTURE DIRECTIONS

We hope that the research presented here will fill a void in the current literature in engineering ethics. The novel survey analysis tool and its application to a wide variety of courses at nine separate universities is one of the most extensive evaluative studies of engineering ethics coursework to date. Though this research is a pilot study, we hope it will provide valuable preliminary information about how effectively such courses impact students' desires to remain engineers and their awareness of ethical and social issues in engineering and technology. In particular, we anticipate some interesting results about how these courses impact the attitudes of women and underrepresented minorities.

Practically-speaking, we learned through the course of this study that the I-Pod Nano lottery did not provide students with a great enough incentive to participate. In future iterations of this study, we hope to use extra-credit in the course as an incentive that could potentially be more enticing. Because of the nature and time-constraints of this project, only a semester-long study was feasible. Because some research indicates that impacts of single courses may be short-lived or negligible, a longer-term study would be a next useful step [6]. For similar reasons, a longer-term study to evaluate long-term curricular versus single-course approaches would be useful. Finally, we hope to extend this project to include a focus-group or interview component with both students and professors to allow a more in-depth understanding of the impacts of these interventions on all parties.

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APPENDIX A: SAMPLE QUESTIONS FROM PARTS II, III, AND IV OF SURVEY

PART II

Q11
How many days in the past week did you read about news or current affairs on the internet or in a newspaper?
0. None
1. One
2. Two
3. Three
4. Four
5. Five
6. Six
7. Seven

Q15
During the past 12 months, have you done any of the following?
[RANDOMIZE QUESTION ORDER]

15A Have you signed a petition?

1 Yes
2 No

15B Attended a political meeting or rally?

1 Yes
2 No

15C Participated in any demonstrations, protests, boycotts, or marches?

1 Yes
2 No

15D Donated blood?

1 Yes
2 No

15E Written a letter to any public officials, giving them your opinion about an issue?

1. Yes
2. No

15F Attended a meeting of a social organization or club?

1. Yes
2. No

Q18
Please rate the importance of each of the following values as a guiding principle in your life. (-1) represents “opposed to my principles,” (0) represents “not important,” and (7) represents “of supreme importance.” [ROTATE OPTIONS]

BENEVOLENCE (that is, helpfulness, forgivingness, and social justice)
-1 0 1 2 3 4 5 6 7
ACHIEVEMENT (that is, success, wealth, and ambition)
-1 0 1 2 3 4 5 6 7
UNIVERSALISM (that is honesty, broadmindedness, protecting the environment, and meaning in life)
-1 0 1 2 3 4 5 6 7
POWER (that is, social power and authority)
-1 0 1 2 3 4 5 6 7
SELF-DIRECTION (that is, creativity, freedom, independence, ability, wisdom)
-1 0 1 2 3 4 5 6 7
SECURITY (that is, family security, national security, and social order)
-1 0 1 2 3 4 5 6 7

PART III

Q19
Different factors influence students' decisions to enroll in an engineering field as undergraduates. In this section please indicate the TOP THREE factors that influenced your decision to enroll in your current degree program.

1. Interest in math and science
2. Natural ability in math and science
3. Participation in science fairs and science outreach programs
4. Encouragement of parents/family members
5. Encouragement of teachers or other mentors
6. Potential for excellent salary
7. Potential for excellent job security
8. Desire to be challenged
9. Potential to make a difference in the world

10. An interesting major

Q25A-G [ROTATE Q25A-G]

HOW IMPORTANT do you think each of the following factors is in adequately fulfilling your responsibilities in the workforce as an Engineer?

Q25A
Loyalty to your employer?

1. Very important
2. Somewhat important
3. Not very important
4. Not at all important

Q25B
Loyalty to your clients (that is, the people or company paying you for your professional services)?

1. Very important
2. Somewhat important
3. Not very important
4. Not at all important

Q25C
Reporting to your manager any activity that seems unethical?

1. Very important
2. Somewhat important
3. Not very important
4. Not at all important

Q25D
Doing no harm to society?

1. Very important
2. Somewhat important
3. Not very important
4. Not at all important

Q25E
Doing no harm to the environment?

1. Very important
2. Somewhat important
3. Not very important
4. Not at all important

Q25F
Helping to improve society?

1. Very important
2. Somewhat important
3. Not very important
4. Not at all important

Q25G
Helping to preserve the environment?

1. Very important
2. Somewhat important
3. Not very important
4. Not at all important

Q26
Engineer A has been hired by a corporate executive to design a certain project. The client would like the design to be simplified, but Engineer A believes a simpler design could be less structurally or mechanically sound. Engineer B has agreed to finish the design to the client's liking. The client asks Engineer A to give the drawings to Engineer B so the project can be finished. The client will pay Engineer A for his work up to this point.

Do you think that Engineer A is obligated to give Engineer B the drawings?

1. Yes
2. No

Please explain your choice.

[WRITE IN BOX]

Q28
Which statement comes closer to your opinion:

1. Engineers must first create new technologies and then find ways they can be used in society.

2. Engineers must first identify social needs and then create new technologies to address them.

Part IV

Q30
Do you intend to graduate from the program/major in which you are currently enrolled?
1. Yes
2. No [SKIP TO Q32]

Q31
Why? Please select top THREE answers. [RANDOMIZE, SKIP to Q33]

1. I enjoy engineering, math, and science coursework
2. I am good at engineering, math, and science coursework
3. I feel I will be able to find a high-paying job
4. I feel I will be prepared for a good graduate school
5. I enjoy the faculty in my department
6. I will be able to contribute to society greatly as an engineer
7. I enjoy the students in my department
8. I am stubborn and wouldn't want to quit
9. My family expects it
10. Other (Please specify) [FILL IN]

Q32

Why not? Please select top THREE answers.
[RANDOMIZE]

1. I don't enjoy engineering, math, and science coursework
2. I am not good at engineering, math, and science coursework
3. I don't think I will be able to find a high-paying job
4. I don't think I will be adequately prepared for a good graduate school
5. I don't think the department provides adequate guidance to students
6. I feel I could contribute more to society with a different career choice
7. I dislike the students in my department
8. I don't fit in
9. I like another major better
10. I want to have a life, and the time demands of engineering are too great
11. Other (Please specify) [WRITE IN]

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