Assessment of a Case Study Laboratory to Increase Awareness of Ethical Issues in Engineering

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***Abstract*—Case studies in engineering ethics were integrated into a first course in electrical and computer engineering at Worcester Polytechnic Institute (WPI), Worcester, MA, with the primary objective of increasing students' awareness of ethical issues in the workplace. During a three-hour "laboratory" period, students read and discussed three short case studies in engineering ethics, focusing on understanding the differing viewpoints of individuals within a case and identifying multiple courses of action for resolving the issue. The effects of the laboratory were assessed via student focus groups and surveys. All focus group participants agreed that their awareness of ethical issues in engineering was enhanced by the laboratory. In contrast, the survey results were equivocal, showing improvement in the students' awareness of ethical issues; however, the particular questions found to differ statistically preintervention versus postintervention were not consistent between course offerings.**

***Index Terms*—Assessment, case studies, engineering education, engineering ethics.**

I. Introduction

ETHICAL issues are frequently confronted in the engineering workplace. These issues range from minor "white lie" issues to major issues that impact society in general (e.g., the frequently studied explosion of the space shuttle Challenger [2]–[4]). The Accreditation Board of Engineering and Technology (ABET) has recognized these concerns, requiring that all programs they accredit demonstrate that their graduates acquire "... an understanding of professional and ethical responsibility" [5]. Accordingly, many engineering programs incorporate a stand-alone required course in engineering ethics [6]. However, ethical issues in the workplace are frequently intertwined with technical judgments related to product design, development, testing, etc. Hence, incorporation of ethics education into the technical curriculum is a desirable option, from both the perspectives of efficiency and effectiveness [7]–[12].

In addition, many ethical issues, particularly issues with major impact, do not simply arise instantaneously. Rather, precursor decisions often establish precedence and/or faulty decision systems [2]–[4]. Thus, early awareness and identification of ethical issues might facilitate resolution prior to the time when an issue has major impact. Said another way, "... good ethics can prevent problems before they arise" [4].

The electrical and computer engineering (ECE) curriculum at Worcester Polytechnic Institute (WPI), Worcester, MA, has a single entry point, a basic course in electronic circuits. This course is typically taken in the first year by all ECE students, and at any time by students in other majors. In addition to teaching basic electronic circuits, this course is intended to serve as an introduction to the fields of electrical and computer engineering. As such, this gateway course is an appropriate place for the introduction of engineering ethics.

The ethics component of the course was developed around a three-hour ethics case study laboratory. The primary objective of the laboratory was to increase students' awareness of ethical issues in the workplace. The experiment was conducted in two phases, with the ethics laboratory held during the first calendar week of each course offering. In Phase I, students in two course offerings participated in the laboratory and were assessed on their ability to generate different courses of action to resolve an ethical conflict. Results of this work have been reported previously [1]. The Phase II effort is the topic of this report and is outlined in Fig. 1. The assessment work for Phase II began with focus group evaluation of students who participated in the Phase I laboratories in spring 2001. Based on the Phase I assessments and the focus group results, the laboratory and assessment instruments were modified and applied to two subsequent course offerings in fall 2001 (August–October) and spring 2002 (March–April). The ensuing sections describe the Phase II effort—the focus groups, the Phase II ethics laboratory, and its assessment and results.

II. Methods

A. Focus Group Sessions

Two focus groups were conducted two weeks after the conclusion of the spring 2001 class by P. Quinn, who had not been present at the laboratory sessions. Potential participants were identified from the roster of spring 2001 students, recruited without specific knowledge that the session would relate to the ethics training and offered $20 in exchange for their participation. A protocol of structured questions directed discussion for two groups and was designed to elicit the following from students:

1) opinions and attitudes about the effects of an ethics intervention on their thinking;

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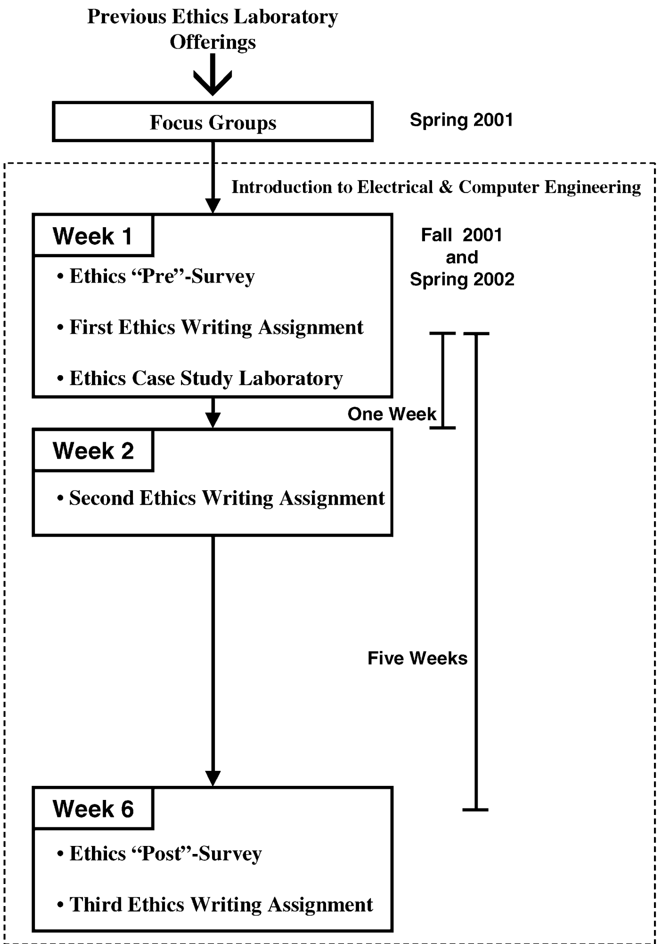

Fig. 1. Schedule of assessment and teaching activities related to the ethics laboratory. Focus groups were conducted in spring 2001. The laboratory was revised and assessed within two subsequent class offerings during fall 2001 and spring 2002.

2) opinions and attitudes regarding current and future encounters with ethically challenging situations;
3) suggestions for future ways to assess changes in student thinking about ethics.

One female and five males participated in the first focus group. Four males participated in the second focus group. Because the same protocol was used for both groups and participation in one group as opposed to the other was based solely on student availability, the findings do not distinguish between groups.

B. Assessment

The Phase II ethics components were delivered to two course offerings, on three separate days per offering, as illustrated in Fig. 1. On day 1, students participated in an assessment "presurvey," completed a written ethics assignment, and participated in the ethics case study laboratory. One week subsequent to the laboratory, the students completed a second writing assignment. Five weeks subsequent to the laboratory, the students completed an assessment "postsurvey" and a third writing assignment. Because undergraduate courses at WPI are conducted in seven weeks, the five-week interval to the "postsurvey" was the largest available while students remained enrolled in the course. Students participating in the assessments did so voluntarily and were awarded bonus points.

The "presurvey" and "postsurvey" instruments were identical, consisting of the 16 Likert-scale questions shown in Table I and some additional demographic items. The questions assessed student agreement with various statements related to business ethics, ethical awareness, and the need for engineers/scientists to understand ethics. For each question, students selected one of six agreement levels: "Strongly Disagree," "Disagree," "Neither Disagree Nor Agree," "Agree," "Strongly Agree," or "No Basis For Judging." No time limit was set for completing the survey; however, most students required less than 10 min.

C. Ethics Case Study Materials

A major goal of the case study laboratory was to help students recognize that ethical issues frequently impinge on the work environment. Accordingly, the authors used case studies based on actual engineering practice. Two public-domain sites on the Internet, the Online Ethics Center for Engineering and Science (http://www.onlineethics.org) and the National Institute for Engineering Ethics (http://www.niee.org), archive brief case studies well suited to the goals of this teaching effort. Cases from these sites were considered appropriate if, in the subjective evaluation of the instructor (E. A. Clancy), they dealt with issues that might be considered relevant to first-year engineering students, did not require specialized training in engineering codes of conduct, and were summarized in one or two paragraphs. From the pool of appropriate cases, three dissimilar cases were selected, one each in public safety, possible omission of relevant information in an engineering report, and ethical conduct as an expert witness. A set of questions followed each case study. The questions guided discussion and forced the students to consider the point of view of conflicting case characters. A complete case study fit onto an 8 1/2 by 11-in page. An example case is given in [1].

D. Ethics Case Study Laboratory Session

At the start of a laboratory session, each student individually completed the presurvey questions shown in Table I. Next, students completed a writing assignment. Three additional case studies were selected as before. These cases considered signing a confidentiality/nonsolicitation agreement, providing a safety consultation report to an investigative journalist, and approving a poor engineering design. For each student, one of the three cases was selected randomly. The remaining case studies were used in the ensuing writing assignments, with the order of presentation randomized for each student. Students were instructed to write as many different courses of action as they could think of that might be used to resolve the ethical issue/dilemma described in their case. Students completed this writing assignment individually in a 10-min time period.

Students then read a copy of the IEEE Code of Ethics (see http://www.ieee.org). This Code is written on a single page and lists ten generic items that must be followed or avoided for achieving high-level ethical and professional conduct. The laboratory class was next divided into discussion groups of not more than eight students each. The groups were instructed

TABLE I

SUMMARY SURVEY RESULTS. MEAN ± STANDARD DEVIATION SURVEY RESPONSE VALUES FOR THE PRESURVEYS AND POSTSURVEYS ARE GIVEN FOR EACH QUESTION FROM THE TWO COURSE OFFERINGS. STUDENTS WERE ASKED TO INDICATE THEIR EXTENT OF AGREEMENT (ONE OF FIVE LIKERT-SCALE OPTIONS) WITH EACH QUESTION, SCORED AS: 1 = STRONGLY DISAGREE, 2 = DISAGREE, 3 = NEITHER DISAGREE NOR AGREE, 4 = AGREE, 5 = STRONGLY AGREE. PRESURVEY VERSUS POSTSURVEY RESPONSES WITH SIGNIFICANCE LEVEL (p) BELOW 0.05 ARE INDICATED IN BOLD FONT

Question	Fall 2001		Spring 2002	
	Pre-	Post-	Pre-	Post-
1) It is important for me to receive some formal training in ethics during my college career.	3.94 ± 0.86	4.03 ± 0.68	3.95 ± 0.79	4.02 ± 0.84
2) It is important for an engineer to be aware that he or she may encounter ethical conflicts in the workplace.	4.47 ± 0.51	4.41 ± 0.56	4.47 ± 0.64	4.42 ± 0.50
3) It is important for an engineer (/scientist) to actively anticipate potential ethical conflicts.	4.03 ± 0.77	4.03 ± 0.59	4.07 ± 0.79	5.07 ± 6.26
4) I would benefit from training in ethics.	3.84 ± 0.77	3.91 ± 0.89	3.77 ± 0.77	3.85 ± 0.98
5) I will encounter ethical dilemmas in my future career.	4.04 ± 0.81	4.29 ± 0.75	4.11 ± 0.70	4.11 ± 0.81
6) I have encountered ethical dilemmas in my past career (school or work).	**3.68 ± 1.14**	**4.06 ± 0.73**	3.56 ± 0.94	3.44 ± 1.16
7) If a person has a clear understanding of ethical standards, then solutions to most ethical conflicts can be readily ascertained.	3.53 ± 1.11	3.38 ± 1.04	2.88 ± 1.29	2.88 ± 1.11
8) There is often a right way and a wrong way to resolve an ethical conflict.	2.90 ± 1.14	3.13 ± 1.15	2.98 ± 1.21	2.76 ± 1.18
9) As long as I'm doing my job the way it's supposed to be done, I won't experience ethical conflicts.	**2.09 ± 0.78**	**1.72 ± 0.52**	2.10 ± 0.83	1.95 ± 0.63
10) One's religious beliefs should be the primary consideration when attempting to resolve an ethical conflict.	2.20 ± 1.21	2.13 ± 1.07	2.00 ± 0.87	1.93 ± 0.98
11) One's personal well being should be the primary consideration when attempting to resolve an ethical conflict.	2.84 ± 1.21	2.84 ± 0.86	2.78 ± 1.21	2.98 ± 1.19
12) The best interests of the employer should be the primary consideration when attempting to resolve an ethical conflict.	2.31 ± 0.89	2.38 ± 0.86	2.27 ± 1.00	2.37 ± 0.80
13) The overall good of everyone involved should be the primary consideration when attempting to resolve an ethical conflict.	3.97 ± 0.96	3.73 ± 1.05	3.77 ± 0.92	3.88 ± 0.72
14) Minimizing financial loss should be the primary consideration when attempting to resolve an ethical conflict.	2.47 ± 0.90	2.03 ± 0.96	2.17 ± 0.93	2.15 ± 0.86
15) The primary consideration when attempting to solve an ethical conflict will vary from situation to situation.	4.39 ± 0.66	4.36 ± 0.74	4.15 ± 0.83	4.28 ± 0.91
16) A code of ethics for engineers would be useful to have.	3.97 ± 0.93	4.00 ± 0.67	**3.68 ± 0.96**	**4.10 ± 0.86**

to read and then discuss the "public safety" case within their group, using the discussion questions as a guide. A "recording secretary" from each group was responsible for recording written responses to each case study question. Groups were given 20 min to discuss the case and record their discussion. The second and third case studies were similarly distributed and discussed. To encourage participation of all group members, a different recording secretary was required for each case. These group-based discussions lasted a total of 60 min.

Each group then led the presentation of one case in front of the class. Discussion of concurring, dissenting, and additional opinions was encouraged from remaining group members and from members of other groups. The instructor helped to keep discussion focused and presented dissenting views when none were offered by the students. When student discussion of each case was complete, the instructor presented the case's actual resolution. The instructor provided concluding comments to reinforce the major learning objectives, reminding students of the following:

1) ethical issues do arise frequently in the workplace;
2) opinions as to what is/is not ethical vary from person to person [13];
3) ethical conduct is not always rewarded in the workplace and can even lead to negative repercussions [3], [14];
4) ethical issues may be resolved with many different courses of action;
5) many ethical conflicts are best resolved early;
6) the laboratory served only as an introduction to ethical issues with the case study descriptions being summary in nature.

Students with additional interest in these studies were referred to full-length ethics courses offered by the Institute.

III. RESULTS

A. *Focus Group Results*

To varying degrees, all students agreed that training in ethics in engineering was beneficial. Two popular positions were that 1) ethics training should be offered to student engineers because they often are unaware that ethical conflicts arise during employment and 2) attempts to train students to behave in prescribed ways that are inconsistent with their current values will not be successful since students' values and morals have already been formed. Nonetheless, exposure to ethical conflicts heightens awareness of potential conflicts and prepares students for handling or preventing them.

Regardless of the ethics knowledge students had upon entering the course, they all agreed that their awareness of ethical issues in engineering was enhanced by the ethics laboratory. For students who entered the class ignorant of ethical conflicts in engineering, the laboratory broadened their understanding of the field of engineering to include ethics. For students who entered the class already aware that ethical considerations were entwined with the field of engineering, the laboratory broadened their understanding of the potential complexity of ethical dilemmas and helped them to think about these issues in slightly different ways.

The ethics training received by the students consisted of an introduction to the IEEE Code of Ethics, individual written work on solution generation for ethical dilemma case studies, small discussion group work on solution generation for ethical dilemma case studies, and presentation of their own and observation of others' group-generated solutions to case studies. While not all students agreed that each of these aspects of the ethics training was beneficial, there was agreement by most students that every aspect contributed to raising their awareness of ethical issues in engineering. Most students believed that exposure to the IEEE Code of Ethics helped to broaden their thinking about ethical issues in engineering, with some indicating that they had even used items of the Code in resolving case study dilemmas. Students believed they benefited from working on multiple case studies individually because they were exposed to a diverse set of ethical conflicts, and they gained experience at generating solutions to these situations. Exposure to the ideas of others through small-discussion-group work and observation of others' presentations served as a source of inspiration as they encountered new case studies themselves. In addition, students indicated that they had proceeded more easily with those cases in which they had an understanding of some specific issues that were involved or when their own sense of ethics seemed well aligned with possible solutions.

B. Survey Results

In fall 2001, 41 students completed surveys, with 33 (four women and 29 men) participating in both the presurvey and postsurvey. In spring 2002, 49 students completed surveys, with 42 (two women and 40 men) participating in both the presruvey and postsurvey. Presurvey and postsurvey data were compared for each question using a Wilcoxon matched-pairs test. When blank or "No Basis for Judging" responses occurred, the student's response, for that question only, was removed from the statistical analysis. The number of available student-response pairs, per question, ranged from 24 to 33 for fall 2001 and 36 to 42 for spring 2002. Data from the two course offerings were analyzed separately.

Table I presents summary results for both course offerings. Note that this table lists the mean and standard deviation of the responses for each survey question to enable the reader to more easily compare the changes from presurvey to postsurvey. In contrast, the Wilcoxon matched-pairs test used in the statistical comparisons utilizes rank sums. For fall 2001, survey responses indicated that students improved in their ability to recognize ethical dilemmas. When asked how much they agreed that they had encountered ethical dilemmas in their past school/work careers, average postsurvey responses registered "Agree" while presurvey responses registered between "Neither Disagree Nor Agree" and "Agree," and the difference was statistically significant (Question 6; $T(n = 31) = 27.5, p = 0.036$). When asked how much they agreed that performing their job as it should be done would result in avoiding ethical conflicts, average postsurvey responses registered between "Disagree" and "Strongly Disagree," while presurvey responses only registered "Disagree," this difference being statistically significant (Question 9; $T(n = 32) = 11.0, p = 0.028$). No statistically significant differences were found for the other questions $(p > 0.05)$.

For spring 2002, a different survey question suggested an increase in the students' awareness of ethical issues. When asked how much they agreed that a code of ethics for engineers would be useful, average postsurvey responses registered "Agree" while presurvey responses registered between "Neither Disagree Nor Agree" and "Agree," a statistically significant difference (Question 16; $T(n = 41) = 28.0, p = 0.012$). All other response differences were not statistically significant $(p > 0.05)$.

IV. Discussion

Because the intervention was relatively short in duration (three class days, centered around one 3-h laboratory), the outcome goal of increased ethical awareness was appropriately limited. Larger scope goals would be consistent with longer duration interventions, e.g., a semester-long course in engineering ethics [15]. The results in demonstrating achievement of the goal via formal assessment were mixed. In support of this goal, all focus group participants agreed that their awareness of ethical issues in engineering was enhanced by the laboratory. In addition, three of the 16 survey questions achieved statistical significance in indicating an increase in students' awareness of ethical issues. In contrast, no single survey question showed significant positive change for both course offerings. Hence, the presurvey versus postsurvey changes are equivocal. Perhaps a larger sample size is required to measure more definitively the presence or absence of an effect.

Other anecdotal observations support the notion that even this brief ethics training had an impact on the students. Students in a sophomore-level, follow-on engineering course have been given ethics assignments as part of their weekly homework, and they have noted to their course professor that they are used to having ethics assignments intertwined within a technical course. In addition, students from the course that included the ethics laboratory have contacted the course professor later in their career to discuss ethics issues, citing the laboratory experience as the reason for seeking out that particular professor.

In addition to E. A. Clancy, two ECE faculty who were new to teaching this course now conduct the ethics laboratory. Most helpful in gaining adoption of the laboratory by these faculty members was the following:

1) there was an otherwise unused laboratory slot during the first class week;
2) all necessary materials for the ethics laboratory were available;
3) E. A. Clancy helped the instructor with the first course offering.

The only drawback identified by one of the new faculty is the faculty time commitment required. The task cannot easily be assigned to teaching assistants; thus, faculty were committed to three hours per laboratory session for each of two to three sections. Between 2000 and 2004, approximately 600 students in seven course offerings have completed the laboratory. Faculty with previous experience teaching this course have not offered the new laboratory, nor has a request been made of them to do so.

The ethics laboratory in this course is but one facet of the training in professional and ethical responsibility provided to these students. Students who continue in the ECE curriculum receive additional formal ethics training in a sophomore-level engineering design course, and often in other courses, departmentwide seminars, and their senior projects. Finally, instructors must always be reminded that their own conduct and behavior as teachers is perhaps the most influential ethical training given to students. As a course is taught, the instructor interacts with students on a daily basis. If the students are always treated fairly and with dignity and respect, then the instructor daily reinforces the ethical conduct encouraged by this profession. If, however, ethics is taught, but the instructor does not abide by ethical standards, he or she is not likely to remain credible in their eyes.

V. Summary and Conclusion

Students in a basic electronics course took part in an ethics case study laboratory, which had the primary goal of increasing students' awareness of ethical issues in the workplace. Focus groups who had participated in an earlier version of the laboratory revealed student opinions that exposure to ethical conflicts in engineering heightens student awareness of them; heightened awareness of potential ethical conflicts may aid in preventing/avoiding them; professional engineers are more likely than students to encounter ethically challenging situations; exposure to the IEEE Code of Ethics is useful to most students; and familiarity with specific issues related to an ethically challenging situation enhances one's ability to generate resolutions. Two subsequent course offerings assessed increases in ethical awareness via a survey instrument. The survey was administered prior to the laboratory, and again after five weeks. A few statistically significant improvements in ethical awareness were found; however, the particular questions found to differ presurvey versus postlaboratory were not consistent over two course offerings.

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