USING CASE STUDIES TO INCREASE AWARENESS OF, AND IMPROVE RESOLUTION STRATEGIES FOR, 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 with the primary goals of increasing students' awareness of 1) ethical issues in the workplace, and 2) the number of different courses of action that one might take to resolve the ethical issues. During a three-hour "laboratory" period, students read and discussed four short case studies in engineering ethics. Discussion was guided to focus on understanding the (often conflicting) viewpoints of individuals within a case and to look for multiple courses of action for resolving the issue. The second learning goal was assessed prior to the case study laboratory and on two occurrences after the laboratory. Assessment results showed no changes in the number of different courses of action that students could enumerate to resolve ethical issues. Nonetheless, this laboratory might still 1) encourage students to take a full-semester ethics course (which could lead to measurable results), 2) contribute to progressive learning in this area, and 3) begin (in a way we have yet to measure) to convince students that ethics is an important aspect of their career paths.*

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

INTRODUCTION

Far more often than we would like to admit, ethical issues and interpersonal conflicts are confronted in the engineering workplace. The scale of these issues ranges from minor conflicts involving one or a few people to major conflicts whose outcome impacts many in the engineering profession and society in general (e.g., the frequently studied explosion of the space shuttle Challenger [2], [5], [9]). Ethical issues that arise in the workplace are frequently intertwined with technical judgments related to product design, development, testing, etc. However, classical engineering education may not adequately address learning needs in this area, particularly the incorporation of ethical decision making directly into technical courses. Hence, incorporation of ethics education into the technical curriculum is an important topic [6]–[8]. In addition, many ethical issues (particularly issues with major impact) do not simply arise instantaneously. Rather, precursor decisions (frequently of lesser impact) often establish precedence and/or faulty decision systems. (Again, see discussions of the Challenger incident [2], [5], [9].) Thus, early identification of ethical issues might facilitate resolution prior to the time when an issue might have major impact. Said another way, "... good ethics can prevent problems before they arise." [9] Finally, what constitutes an ethical issue and its acceptable resolution can vary considerably from person to person (c.f., Fielder and Lawler [4]). Thus, conflict resolution skills that stress each individual's understanding of the ethical concerns and that search for multiple alternatives are important skills to develop in engineering students.

The Electrical and Computer Engineering (ECE) curriculum at WPI has a single entry point, a basic course in electronic circuits. This course is typically taken in the freshman year by all ECE students, and is taken at any time by students in other engineering and science 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, the introduction of engineering ethics within this gateway course is appropriate.

The ethics component of the course was delivered on three separate days. On the first day, students began by completing an initial ethics assessment. This first assessment established a baseline measurement for each student. On this same first day, the students then participated in the intervention portion of their ethics studies — a three-hour ethics case study laboratory. One week and five weeks subsequent to the case study laboratory, the students were again assessed, for a total of three assessments. The purpose of the second assessment was to measure the short-term effects of the intervention. The purpose of the third assessment was to measure the longer-term effects of the invervention. Ideally, the third assessment would have been conducted at some date extending beyond the conclusion of the course, however it was conducted near the conclusion of the course to ensure higher participitation rates. The case study laboratory and the assessments are described in detail in the next sections.

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CASE STUDY METHODS

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, it was desired to use case studies based on actual engineering practice. Fortunately, two public-domain sites on the Internet archive brief case studies well suited for the goals of this teaching effort. The Online Ethics Center for Engineering and Science [11] has as its mission to "... provide engineers, scientists, and science and engineering students with resources for understanding and addressing ethically significant problems that arise in their work, and to serve those who are promoting learning and advancing the understanding of responsible research and practice in science and engineering." In addition to an archive of case studies, this site maintains several resources including an ethics help-line, detailed accounts of engineers or scientists who have demonstrated exemplary behavior in difficult ethics situations, and codes of ethics from several engineering and scientific societies. The National Institute for Engineering Ethics [12] has as its mission to "... promote the study and application of ethics in our nation's engineering schools and throughout the engineering profession." The NIEE serves "...as an independent liaison organization to promote engineering ethics among all engineering disciplines." Additional resources available on this site include an ethics resource guide, a true/false exam testing knowledge of the National Society of Professional Engineers (NSPE) code of ethics, and links to numerous other ethics resources. Note that the NIEE developed the well-known engineering ethics video "Gilbane Gold".

The archived cases from both of these sites were searched and appropriate cases identified. Cases were considered appropriate if, in the subjective evaluation of the instructor, they dealt with issues that might be considered relevant to first year engineering students, did not require specialized training in engineering codes of conduct (e.g., certain financial conflict of interest issues may legally hinge on the definitions of a contractor, an agent, etc. — issues that are not common knowledge to these students), and could be restated in one or two paragraphs. From the pool of appropriate cases, four dissimilar cases (one each dealing with public safety, possible omission of relevant information in an engineering report, a decision on whether or not to approve a poor engineering design, and ethical conduct as an expert witness) were selected.

If necessary, the cases were edited to a length of not more than two paragraphs. In addition, the facts of the case were adjusted (where necessary) to avoid presenting any obviously "correct" ethical choice or course of action. Rather, a purpose of the case study laboratory was to encourage debate as to the ethical choices and courses of action available to each case study character. Finally, a set of questions followed each case study. (Such questions were often provided by the Internet case study archives mentioned above.) The questions guided discussion of the case issues and forced the students to consider the point of view of conflicting case characters. A last question, identical to that used for assessment (discussed in the next section), was included. The question asked the students to list *as many different* courses of action as possible that each case character might take to resolve the ethical issue/dilemma described in the case. This task helped focus discussion on one of the major learning goals of the ethics work — improving students' ability to develop resolution strategies. A complete case study (title, description, discussion questions and references) fit easily onto an 8 ½ by 11 inch page. An example case is shown in Appendix A.

Ethics Case Study Laboratory Session

All students participated in the case study laboratory on the same calendar day, but during three consecutive sessions. One third of the students attended each session, based on their course registration. At the start of a laboratory session, each student individually completed the first assessment. (Assessment is discussed in the next section.) Upon completion of the assessment, each student read a copy of the Institute of Electrical and Electronics Engineers (IEEE) Code of Ethics. (This code can be found on the IEEE web site [13].) The IEEE Code of Ethics is written in a single page and lists ten generic items that must be adhered to or avoided for achieving high ethical and professional conduct. These generic items were appropriate for this laboratory (rather than an exhaustive enumerated list of acceptable/unacceptable practices), since general, innate principles of ethical conduct were explored in this laboratory. Moreover, the preamble to the IEEE ethics code affirms the commitment to ethical conduct by the profession thereby legitimizing its endorsement in this laboratory.

The laboratory class was next divided into discussion groups of not more than eight students each. The discussion groups were separated into different areas of the classroom (to limit communication *between* the groups) and then given the first case study. The groups were instructed to read and then discuss the 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. The instructor did not take part in the discussions, but circulated among the groups to encourage participation from all group members, encourage consideration of the concerns of all case characters, and to ensure that responses to the questions were recorded in writing. Groups were given 20 minutes to discuss the case and record their discussion.

When the first case discussion period was complete, the second case study was distributed. The 20 minute reading, discussion and recording process was repeated. The third and fourth case studies were similarly distributed. To

encourage participation of all group members, a different recording secretary was required for each case. These group-based discussions lasted a total of 20x4=80 minutes.

The cases were then discussed in front of the entire laboratory class. To do so, each group was assigned to lead the discussion of one case. The groups were given ten additional minutes to select a discussion leader (someone other than one of the four recording secretaries) and organize their discussion points. Additionally, each group transferred their answers to the final case question (enumerating resolving courses of action) to an overhead projector transparency. The group leader of the first case then led the class in an open discussion of their group's answers to each question (except for the final question). Discussion of concurring and dissenting opinions, both from remaining group members and from members of other groups, was encouraged. The instructor helped to keep discussion focused, and represented dissenting views when none were offered by the laboratory class. In this manner, the instructor encouraged the students to consider more facets of the ethical situation than the students were uncovering on their own. For the final case question (enumerating resolving courses of action), the group leader reviewed the group's answers using an overhead projector. Then, *all* other distinct responses from the other groups were solicited and added to those of the presenting group. The remaining three cases were similarly discussed in front of the entire laboratory class. Each discussion lasted approximately 10 minutes. When more than four student groups had been formed, presentation of some cases was shared by two groups. Lastly, the instructor provided concluding and summary comments to wrap-up the case study session and reinforce some of the major learning objectives. With these comments, students were reminded that 1) ethical issues do arise frequently in the work place, 2) opinions as to what is/is not ethical vary from person to person, 3) ethical conduct is not always rewarded in the work place, and can even lead to negative repercussions (see [3] and the Bay Area Rapid Transit System case in [5]), 4) ethical and interpersonal conflict may be resolved with many different courses of action, and 5) many ethical and interpersonal conflicts are best resolved early, hence early identification of these issues can be imperative.

ASSESSMENT METHODS

Assessment was directed towards the second teaching goal, that of increasing the number of different courses of action that one might take to resolve ethical issues. (Assessing the first teaching goal of increasing awareness to ethical issues was avoided since administering the assessment in this engineering course *announces* that ethical issues are being presented.) For assessment, three additional case studies (one per assessment) were selected in the same manner as described above (one each dealing with a confidentiality/ non-solicitation agreement, providing safety consultation to be used by an investigative journalist, and misuse of a software licensing agreement). These assessment cases were similar in complexity and ambiguity to the previously described cases used during the laboratory intervention. Rather than provide discussion questions, students were instructed to do the following: "List *as many* <u>*different*</u> courses of action as you can think of that might be used to resolve the ethical issue/dilemma described in this case. You may list courses of action that may have been taken at any time before, during, or after the events given in the case description. If appropriate, make a separate list for each case character. Number your responses as '1.', '2.', '3.', etc."

Students completed each of three assessments individually in a 15 minute time period. Students participated in the assessments voluntarily and were awarded "bonus points" for their participation. The baseline assessment was completed as the first event in the ethics case study laboratory. The second and third assessments were completed one week and five weeks subsequent to the ethics case study laboratory. To avoid potential order effects, the order of presentation of the three assessment case studies was randomized and counterbalanced to the fullest extent possible.

To measure the effects of the intervention on students' ability to generate multiple resolutions to ethical conflicts, frequency counts of the number of resolutions enumerated by each student on each case study assessment were obtained. The possible range of number of resolutions per case study ranged from zero to infinity. Frequency counts were obtained by a trained, blinded rater (blinded to the order that each student completed the assessments). The rater counted a response as a valid course of action if the written response was 1) legible, 2) an *action* that any case study character might take (e.g., a response such as "Hope that things work out for the best," was not counted since it is a passive approach that has no chance of influencing the course of events), 3) significantly different from other courses of action that had been proposed (e.g., "Quit," and "Work elsewhere," were considered duplicate actions, and only one counted), 4) relevant to the case at hand (e.g., "File bankruptcy," was not counted as a valid action in a case wherein financial solvency was not at issue), and 5) more than merely an evaluative statement (e.g., responses were not counted if they consisted of an essay describing the student's opinion on the case, rather than suggesting courses of action). The number of courses of action was not determined by recording the final number listed on the response sheet, but rather by the number of valid actions a student provided. (At times, students included more than one valid action within a single numbered course of action.)

RESULTS

A total of 112 students enrolled in the initial assessment and actively participated in the case study laboratory. During the oral presentations at the end of the laboratory, additional courses of action were offered by the non-presenting groups for every case. Of the initial participants, 95 (16 women, 79 men) completed all three assessments and the case study laboratory. Frequency counts of the number of resolutions enumerated by these 95 students were analyzed. Table I summarizes the frequency counts by assessment case study. A one-way, within subjects analysis of variance (ANOVA) was used to test if response counts differed by assessment case. The analysis showed a significant difference between assessment cases [$F(2, 188) = 4.64$, $p = 0.01$]. Therefore, there was a statistically significant difference in the number of courses of action written for the three cases.

Table II summarizes the frequency counts by assessment day. A one-way, within subjects ANOVA was used to test if frequency count results differed by assessment day. This analysis showed no significant difference [$F(2, 188) = 0.59$, $p = 0.55$] between assessment days. Therefore, there was no statistically significant increase in the number of courses of action written by the students after their participation in the case study laboratory.

The subject data were also separated by gender and the total number of responses (summed from the three assessments) compared between females and males. Table III summarizes the summed frequency counts by gender. A *t*-test accepted the hypothesis that these frequency counts did not differ by gender [$t(93) = 0.42$, $p = 0.68$]. Therefore, there was no statistically significant difference in the number of courses of action written by the females as compared to the males.

TABLE I

FREQUENCY COUNTS OF THE NUMBER OF DIFFERENT COURSES OF ACTION ENUMERATED BY THE STUDENTS — SUMMARY STATISTICS FOR EACH OF THE THREE ASSESSMENT *CASES*.

	Case 1: Engineer Tom	Case 2: Engineer Lorinda	Case 3: Engineer Robert
Minimum	0	1	0
Maximum	21	15	16
Median	5	6	6
Mean	6.07	6.16	6.86
Std. Dev.	3.30	2.86	2.73

TABLE II

FREQUENCY COUNTS OF THE NUMBER OF DIFFERENT COURSES OF ACTION ENUMERATED BY THE STUDENTS — SUMMARY STATISTICS FOR EACH OF THE THREE ASSESSMENT *DAYS*.

	Day 1	Day 2	Day 3
Minimum	1	0	0
Maximum	16	15	21
Median	6	6	6
Mean	6.21	6.53	6.36
Std. Dev.	2.76	2.96	3.24

TABLE III

FREQUENCY COUNTS OF THE NUMBER OF DIFFERENT COURSES OF ACTION ENUMERATED BY THE STUDENTS — SUMMARY STATISTICS COMPARING TOTAL RESPONSES (SUMMED OVER THREE ASSESSMENTS) BETWEEN FEMALES AND MALES.

	Females (N=16)	Males (N=79)
Mean	18.38	19.24
Std. Dev.	8.27	7.41

DISCUSSION

Our primary goals in this case study laboratory were to increase student's awareness of ethical issues in the workplace and the number of different courses of action one might take to resolve ethical issues. Our assessment concentrated on the latter goal by counting the number of different courses of action that students could enumerate for short ethical case studies. We found that the three-hour ethics "laboratory" intervention did *not* lead to an increase in the number of resolving courses of action written by the students (neither one week nor five weeks after the intervention). This result was surprising because a wide range of resolutions (beyond the number recorded by any individual group) were discussed during the oral presentation portion of the laboratory. Hence, all students were exposed to a large number of alternative resolution strategies, many of which are transferable to other ethical situations. However, even after a duration of only one week, students were not able to write any more resolving actions, on average, than before the laboratory intervention.

Perhaps the intervention was too short in duration to elicit a measurable improvement in the ability to enumerate multiple resolutions. Certainly other fields have found short-duration interventions to have no measurable effect. For example, Daltroy *et al.* [1] studied a classical "back school" which consisted of three hours of education and limited follow-up sessions. They found no influence on this training and the goal of reducing low back injury. In contrast, Self and Ellison [10] assessed improvement in moral reasoning skills due to the intervention of a semester-long course in engineering ethics. They were able to measure an improvement using a standardized questionnaire.

If increasing the number of resolving courses of action is not a successful metric, then perhaps additional attention should be paid to the other major goal of increasing awareness of ethical issues in the workplace. In particular, one result of the laboratory intervention might be to funnel interested students into a full course in engineering ethics. Hence, it may be appropriate to add to the laboratory

summary and conclusion wrap-up comments an "advertisement" for ethics courses available on campus.

Because assessment was repeated three times in five weeks, the assessments themselves served as a teaching tool to reinforce the importance of ethical issues in engineering. In total, the students spent approximately 210 minutes engaged in ethics study activities (assessments and lab) during the course. Of this time, 45 minutes (over 20% of the total time commitment) was dedicated to assessment. Perhaps in the future, such short-duration interventions should concentrate analysis on assessing student's awareness of ethical issues before versus after the intervention.

Finally, we must always be reminded that our own conduct and behavior as teachers is perhaps the most influential ethical training that we give our students. As we teach a course, we interact with students on a daily basis. If we do so fairly, always treating our students with dignity and respect, then we daily reinforce the ethical conduct encouraged by our profession. If, however, we teach ethics but do not abide by ethical standards, we are not likely to remain credible in the eyes of our students.

SUMMARY AND CONCLUSION

Students in a basic electronics course took part in an ethics case study laboratory with the primary goals of increasing students' awareness of ethical issues in the workplace and the number of different courses of action they might take to resolve ethical issues. For the latter goal, students were assessed at three times—prior to the laboratory, one week after the laboratory and three weeks after the laboratory. The assessment consisted of reading a short ethical case study and then writing as many different courses of action to resolve the ethical issues. Counts of the number of written courses of action showed no difference in the number of resolutions before versus after the intervention. Nonetheless, this intervention might still 1) inspire students to take a full-semester ethics course (which could lead to measurable results), 2) contribute to progressive learning in this area, and 3) begin (in a way we have yet to measure) to convince students that ethics is an important aspect of their career paths.

APPENDIX A: EXAMPLE CASE STUDY

Case 1: Responsibility for Public Safety and the Obligation of Client Confidentiality

Tenants in an apartment building sue the owners of the building in order to force them to repair a number of annoying, but not dangerous, problems. The owners' attorney hires Duchane, a structural engineer, to inspect the building and testify on behalf of the owner. Duchane conducts a preliminary inspection, and as a result suspects there may exist serious structural problems in the building that could be an immediate threat to the tenants' safety. These problems, however, are unrelated to the tenants' suit. Duchane reports this information to the attorney and recommends that he return to the building to more fully evaluate the structural problems. The owners' attorney accepts Duchane's report regarding the original complaints of the tenants and tells Duchane to keep the structural concerns confidential because it could affect the lawsuit. Duchane is not contracted to return to the building to more fully evaluate the newly discovered structural problems.

1. Assume that Duchane complies with the attorney's decision to keep the structural concerns confidential.
   - To what extent has he compromised his professional responsibility for the public safety?
   - Is Duchane's responsibility to preserve client confidentiality the same as that of the owners' attorney?
   - If a building fault or collapse were to occur, to what extent would Duchane be responsible, ethically and/or legally, for property loss and injury?
   - Would you expect Duchene's opinion of the situation to be different if someone he knew personally lived in the building?
2. Assume that Duchene disregards the attorney's decision and reports his concerns about the building structure to the tenants.
   - To what extent has he compromised his obligation to preserve client confidentiality?
   - If his report "taints" the existing legal proceedings again the building owners, should Duchane be forced to pay part of any monetary legal judgment against the owner?
   - Will this, or other, owners be less likely to hire professional help to inspect buildings in the future? If so, to what extent would fewer inspections compromise future public safety?
   - To what extent has Duchene destroyed his credibility as a consultant on confidential legal issues? In other words, will any attorney hire Duchene in the future to consult on similar matters?
3. Is there a way to resolve the problem without compromising either Duchane's professional responsibility for the public safety or his obligation to preserve client confidentiality?
4. What do you think you would do in this situation?
5. List *as many <u>different</u>* courses of action as you can think of that might be used to resolve the ethical issue/dilemma described in this case. You may list courses of action that may have been taken at any time before, during, or after the events given in the case description. If appropriate, make a separate list for each case character. Number your responses as "1.", "2.", "3.", etc.

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This case study was derived/modified from:
The Online Ethics Center for Engineering and Science: "Responsibility for Public Safety and the Obligation of Client Confidentiality." National Science Foundation. 5 Sept 1998. [22 Aug 2000].
http://www.onlineethics.org/cases/nspe/ec90-5.html

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REFERENCES

[1] Daltroy L. H., Iversen M. D., Larson M. G., Lew R., Wright E., Ryan J., Zwerling C., Fossel A. H. and Liang M. H., "A Controlled Trial of an Educational Program to Prevent Low Back Injuries," *N. Engl. J. Med.*, Vol. 337, No. 5, pp. 322–328, July 31, 1997.

[2] Dombrowski, P. M., "Can Ethics be Technologized? Lessons from Challenger, Philosophy, and Rhetoric," *IEEE Trans. Professional Communication*, Vol. 38, No. 3, pp. 146–150, 1995.

[3] Fielder, J. H., "Ethical Issues in Biomedical Engineering: The Bjork-Shiley Heart Valve," *IEEE Eng. Med. Biol. Mag.*, Vol. 10, No. 1, pp. 76–78, March 1991.

[4] Fielder, J. and Lawler, P. A., "Making an Engineering Ethics Video: Engineering, Ethical Education, and Adult Learning," *IEEE Eng. Med. Biol. Mag.*, Vol. 17, No. 6, pp. 79–82, 1998.

[5] Fleddermann, C. B., "Engineering Ethics Cases for Electrical and Computer Engineering Students," *IEEE Trans. Education*, Vol. 43, No. 3, pp. 284–287, 2000.

[6] Kremers, M., "Teaching Ethical Thinking in a Technical Writing Course," *IEEE Trans. Professional Communication*, Vol. 32, No. 2, pp. 58–61, 1989.

[7] Lynch, W. T., "Teaching Engineering Ethics in the United States," *IEEE Tech. Soc. Mag.*, Vol. 16, No. 4, pp. 27–36, Winter 1997–1998.

[8] McLean G. F., "Integrating Ethics and Design," *IEEE Tech. Soc. Mag.*, pp. 19–30, Fall 1993.

[9] Rabins M. J. and Harris, C. E. Jr., "Teaching Control Engineering With a Preventive Ethics Slant," *IEEE Control Systems Mag.*, Vol. 16, No. 2, pp. 64–67, April 1996.

[10] Self, D. J. and Ellison E. M., "Teaching Engineering Ethics: Assessment of Its Influence on Moral Reasoning Skills," *J. Eng. Education*, pp. 29–34, January 1998.

[11] Internet world wide web site of the Online Ethics Center for Engineering and Science (http://www.onlineethics.org).

[12] Internet world wide web site of the National Institute for Engineering Ethics (http://www.niee.org).

[13] Internet world wide web site of the Institute of Electrical and Electronics Engineers (http://www.ieee.org).