Engineering Ethics – A Collaboration between Engineering and Philosophy

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Abstract

The College of Engineering at the University of Utah has recently initiated a Center for Engineering Leadership, born out of a recently-awarded grant from the Hewlett Foundation, CLEAR (Communication, Leadership, Ethics, and Research). The Center's goals are to incorporate communication skills, team building, and ethics into the College's eight programs, and throughout the entire 4-year curriculum. To accomplish this, we have used the model of an already successful communication program in Mechanical Engineering, where Teaching Assistants from Humanities are brought into the engineering classes and communication skills are taught as "situational" learning, and we have developed an ethics component involving faculty and TA's from the humanities. This paper will discuss the ethics component of the project.

The College of Engineering and the Department of Philosophy recently collaborated in constructing and teaching "Engineering, Ethics and Society", an upper-division humanities-designated course for the entire campus. The objective of "Engineering, Ethics and Society" is to present a framework of ethical theory to the students and interweave that theory in various presentations of case studies in engineering. The case studies are presented by engineering professors and industry colleagues. In this fashion students learn to recognize ethical aspects of various decisions and what ethical dilemmas they may face as engineers. In addition, a goal is to have one of the two teaching assistants work on modules for placing in other engineering classes in the sophomore and senior year, to ensure coverage of ethics in the entire curriculum.

The paper will cover the structure and content of the course, the population of students within the course, and student feedback. In addition, several faculty members from engineering - including the Associate Dean, and two Professors - are auditing the class, and their feedback is included. Finally, a discussion of future improvements and expansion of the class is presented.

Introduction

Over the last several years, the University of Utah, College of Engineering, has been preparing for its Fall 2003, ABET EC 2000 visit. EC 2000 requires several new and different challenges for students in the College, specifically under Criterion 3, Programs Outcomes and Assessments:

> "… (f) an understanding of professional and ethical responsibility, … (h) the broad education necessary to understand the impact of engineering solutions in a global and societal context,… (j) a knowledge of contemporary issues."

Presently, the College has a two-semester freshman course taught through Undergraduate Studies (UGS), entitled "Community as Idea and Experience: American Perspectives" (humanities designation) and "Community as Idea and Experience: Engineering Ethics" (social science designation). The College and faculty involved in ABET felt that a new course should be introduced which focused on building these skills for our students at the upper division. This new course would not only build upon the UGS series, but also ensure inclusion of our transfer population. We also decided that the course should be a part of the General Education program at the University and be a Humanities Designation. As initial discussions began with the College of Humanities on the ethics class, a similar effort was being undertaken with the College of Humanities in the area of written and oral communication. It was decided to combine all of these skills, including team work skills, and submit a grant to the Hewlett Foundation, under the auspices of CLEAR (Communication, Leadership, Ethics, and Research). The grant was funded and the College of Engineering has recently initiated a Center for Engineering Leadership with the following goals:

- Incorporate communication skills, team building, and ethics into the College's eight programs. The College has programs in Biomedical Engineering, Chemical Engineering, Computer Science, Computer Engineering, Civil Engineering, Electrical Engineering, Materials Science and Engineering, and Mechanical Engineering.

- Ensure that the skills are introduced across all four years of the curriculum, and that they are taught as "situational" learning, that is incorporated into the class work, not simply added on.

Mechanical Engineering has been a successful demonstration of this concept over the last eight years, where Teaching Assistants (TAs) from Humanities are brought into the engineering classes and communication skills are taught.

One of the central features leading to ethical issues for engineers is the precise status of engineering as a profession. The difficulty here is that the nature of the activity of engineering has changed in the last century. Whereas the engineer formerly worked as an individual, more recently engineering has become a matter of corporate activity. This presents special ethical challenges to the engineer. Codes of ethics for engineers single out safety as an ethical matter of paramount importance. This is in keeping with ordinary conceptions of professional activity in which there is generally a component of public good thought to be inherent in the activity itself. The reconstruction of engineering from a largely individual activity to a corporate activity places a professional tension on many engineers. The engineer must be both a professional with obligations to the public for safety and an employee with obligations to the company. These obligations may lead in diverging directions. Some ideas about what makes something a profession increase this tension. The engineer needs to be trained in modes of balancing these professional obligations.

The course was introduced to the students Fall Semester 2003, with Professor Margaret Battin as the instructor. Two TAs were assigned to the course with the goal that one of the TAs would continue the Spring Semester to develop course models concerning engineering ethics case studies. The course was a two-day a week, 3 credit hour offering. The course enrolled 25 students, with the majority of students being from Electrical Engineering; one business student was enrolled.

Since exposure to non-linear modes of thinking may be somewhat alien to the ordinary modes that engineers develop, we believed that a wide range of consultation possibilities needed to be made available to the students. The two TAs were drawn from the philosophy department and had offices there. This building is somewhat removed from the area of campus where engineering students normally have their classes. Following the model established in the communications program for engineers an adjacent office was made available in the engineering building to be held right after class on one day by one TA and on the other day of class by the other TA. This proved to be the most frequently used direct consultation resource by the students. Consultation was also available both by the professor and by the TAs in the philosophy department on alternate days.

Other venues of consultation were also used. A web program was set up on which the syllabus and assignments were posted and this also provided access to email for class participants. Conventional email communication was also established between students and the professor and TAs. Students even had access to the home phone numbers of the professor and TAs.

Course Rationale and Design

One of the central underlying rationales for the course is to train—indeed, re-train—students for thinking through ethical dilemmas. Much of the training of engineering students is in "straight-line" ways—that is, that they are taught to identify a problem, think in a linear way about solutions to it, and then proceed to design these solutions. While this may be a simplistic characterization of engineering, it is still the case that the practical, problem-solving approach of a technical field like engineering is rather different in style from an exploratory field like philosophical ethics. Ethical thinking often requires sensitizing people to see moral issues and dilemmas where they did not notice them before, and to make problems more complex before they can approach resolution.

In an attempt to draw attention to the complexities within ethical dilemmas, the class focused on three ethical theories: utilitarianism, Kantian deontology, and virtue ethics. Each of these theoretical frameworks place importance on elements common to ethical dilemmas. Utilitarianism values the consequences of one's actions, Kantian deontology requires following the right rules and having the right motivation, and virtue ethics focuses on the significance of developing a virtuous character. In easy cases, these three ethical theories will yield the same answer for what to do in many of the situations that call for ethical deliberation. However, the interesting cases are the dilemmas where the details of the problem are such that the ethical theories explored provide conflicting answers about what to do. What makes these cases hard is that each of the elements has a certain intuitive appeal; however, in the hard cases it is not possible to satisfy all of them.

To develop the capacity for this kind of non-linear thinking, the course was designed with an ethic-theoretical framework that permitted exploration of the central ethical theories along with topics in engineering—theories that provide differing views of ethical issues, but are incompatible among themselves: utilitarianism, Kantian deontology, virtue ethics, and so on. In a sense, this is like trying to have students see ethical issues first through lenses of one color, then through lenses of another color, and so on—in this way, the real complexity of problems is illuminated. The text used, Mike W. Martin and Roland Schinzinger's *Ethics in Engineering*, stresses this approach. Most students seemed to relish this way of analyzing problems, and they appeared to enjoy the complexities of this approach despite their more practical technical training. Students were typically quite involved in discussions of case dilemmas, and grew increasingly capable of analyzing from various ethic-theoretical points of view.

The topics covered in the course included many germane to a number of different areas of professional ethics--for example, confidentiality, professional responsibility and loyalty, discrimination and issues about race and gender; whistleblowing, multinational corporations, and professionalism—and a number of issues of particular interest in engineering, especially issues of safety and risk. A series of very distinguished visiting speakers—all senior engineers with very impressive credentials—gave talks, but of course their talks differed in focus and approach; students were encouraged to be alert to these differences. The visiting speakers provided professional balance to the course instructor, whose field is philosophy. These speakers considered problems in the design and manufacture of catheters and vascular access devices, computer issues and intellectual property rights, the design and patenting of light-emitting diodes, the development of pressure sensors and pressure transducers for oil exploration, and many other topics.

Writing assignments also worked to stress the multiple-view ethic-theoretical approach of the course. For example, in the final, multi-stepped assignment that lasted over a period of several weeks and culminated in student presentations. This is discussed in further detail below.

Assignments and Grading

Several different types of assignments were used in the class to enable students to follow the class concepts closely and utilize those concepts, both immediately, and as a final "design" element.

Figure 1 represents the assignment and grading information given students in advance. Figure 2 details the grading criteria for the papers. The grading criteria were geared towards helping engineering students hone their writing and communication skills. In addition, part of the goal for getting students to participate in the project of exploring an ethical dilemma and arguing for one course of action over another was to prepare them for the kinds of experiences they are likely to encounter when they go to work as an engineer, and the grading criteria were intended to promote the skills they will need when faced with difficult situations. During the course of their career they will almost certainly find themselves in situations where they disagree with the actions of a co-worker or supervisor. In these kinds of scenarios, the engineer should be able to present the reasons for their position in a way that will make sense to someone like their supervisor who may not have access to the same information, or who has different motives, and therefore has different reasons and conclusions.

Figure 1. Course Assignments and Grading Information

Working "problem" paragraphs. Short written assignments (approx. 1/2-1 page), responding to problems or study questions assigned weekly by the instructor

Papers. Two short papers (approx 3-5 pp.) on topics assigned by the instructor; some of these papers will be presented in class during "open mike" sessions.

Hour exams and quizzes. There will be two scheduled Hour Exams on the texts, cases, lectures, and related materials covered in class or in assigned readings. There may be announced or unannounced quizzes at any time, including the last week of the semester. There will be no final exam.

Class discussion. Students are expected to participate in class discuss and to display their familiarity with the assigned readings.

Grading. The course grade will be based on written work (50%) and exams and quizzes, if any (50%). Well-informed contributions to class discussion may enhance the base grade.

Figure 2. Grading Criteria for Written Work (Papers and Examinations)

To obtain the maximum grade possible, please:

- answer all parts of the question
- stay focused/balance description and analysis
- state your position
- support your position
- explore both sides of the issue
- show familiarity with readings and lectures
- be charitable
- cite sources

In addition, please show:
- clarity (includes defining terms, spelling, grammar)
- organization of ideas

Our grading criteria also stresses the importance of being charitable to opposing views, and we asked the students to provide reasons why someone might hold the view they are arguing against. Again, this is a way to broaden the scope of the students' abilities to analyze ethical dilemmas and recognize the sometimes subtle complexities involved. The idea is that supervisors may or may not have good reasons for choosing one course of action over another, and an engineer should be equipped to take the supervisor's reasons into account before deciding which action to take. Indeed, the engineer may or may not have good reasons for the conclusions that she has, and it is equally important to be able to recognize and evaluate her own reasons before taking action.

Results and Feedback

The final paper assignment best demonstrates the rather positive results of the students' interaction and learning objectives. The final assignment is detailed in Figure 3 below.

Figure 3. Final Assignment

Multi-step final paper assignment.

Step 1. Case construction. Due October 28. (length open, as necessary).
In this initial step, you are to provide/devise a puzzle case in Engineering Ethics. You may consult with various sources of cases (e.g., www.onlineethics.org), or texts like the one we're using or other Engineering Ethics texts such as that by Harris, Pritchard and Rabins, to locate sample cases (maximum possible grade for finding a case, C); you may embellish and reframe one of these cases (maximum possible grade B+; you must submit the original case with your revision) or devise one of your own (maximum possible grade A; you must include any influencing cases with the case of your own). (Please indicate which you are doing, and of course provide the text and citation for cases you're taking or adapting from elsewhere.)

Step 2. Individual case analysis. Due November 6.
Of the cases submitted in step 1, some 6-7 cases will be selected and assigned to the class. You are to provide in advance a ranked list of which ones you'd like to work on, and will be assigned to a group for a specific case. Each person in the group is to write an INDEPENDENT analysis of the group's case, based on analytic techniques developed in this class. You are expected *not* to discuss the case with other members of your group (or anyone else) during this phase.

Step 3. Consolidation phase. Due November 20.
Each group (following specific instructions to be distributed at the time) will prepare a comprehensive analysis of the case, addressing the arguments and counterarguments made by each member of the group in their independent papers. You are expected to discuss the case with other members of your group during this phase.

Step 4. Presentation dates December 2 and December 4.
The cases and discussion will be presented to the class in the final two weeks of the semester. Each member of each group will present a portion of the group paper, and all members of the group will be expected to engage in discussion of the case before the class.

Note on grading. The work submitting in Steps 1 and 2 will be graded individually. For the paper submitted in Step 3, each member of the group will receive the same grade. For the presentation in Step 4, each person in each group will receive both a joint grade for the group's presentation as a whole and an individual grade for their own performance in presenting, exploring, and defending the positions taken in the group paper.

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For the final group presentations the avenues of consultation that had been established proved to be crucial. The final presentation simulated a group project in the professional sphere of engineering. A deadline was set and the completion of the project required the students to organize themselves and do the work in rapid fashion. Schedules had to be coordinated without much time leeway. The established communication channels allowed for very successful final projects.

As shown in Figure 3, students were required to develop moral-dilemma cases of their own (Step 1). To illustrate the depth of these assignments, three examples are given in Figure 4 (student permission was obtained).

Figure 4. Illustrative Student Case Studies

Case 1. How to Operate A Switch? Charles Cox

A company has chosen a way to implement a switch for their machinery in a production and fabrication plant. There were two possible ways to produce the desired, and necessary, result: in either case there needed to be a large inductor coil in series with the switch, but one method was to have the switch manually, directly, operated (much cheaper), while the other option was to have the switch operated at a distance with a robotic arm to actually disengage the switch (much safer, but much more costly). For various reasons, it was not possible to isolate the inductor from the switch, nor was it possible to set the switch up in any other way.

An inherent safety risk was known for this device: when the switch was opened, the inductor would create a very large spark as the enormous energy required for the device was trying to be maintained by the series inductor coil. The calculations of the design engineers showed that with a reasonable insulation the switch could be safely operated manually. Because of this, and the considerably lower cost involved with this setup, the operations managers chose for the switch to be implemented in this way.

All went well with construction until the switch was nearly finished and implemented - ready for testing. A single project engineer who had worked on the initial design, and had always been relatively skeptical of the manual process, noticed when viewing the almost finished product that there was a path, despite the modest insulation, by which the current through the switch could divert and shock/injure the operator when the switch was opened. Seeing this, the engineer ran several physical calculations on his own time and came to the conclusion that the switch was, indeed, imminently dangerous in its current configuration. Also, being thorough, he looked for ways, using the same already purchased materials, that the switch could be fixed; unfortunately, without a different (significantly more expensive) material to insulate the operator from the switch, there was no way to fix it. The engineer ran further tests, as quickly but carefully as possible, to find the safest and cheapest way to re-implement the switch. The engineer concluded that the switch would have to be rebuilt, and that the use of a robotic arm was ultimately cheaper than using the more costly insulator in a similar design. While certain that his calculations were correct, he decided to check them with a co-worker who had also worked on the initial switch design. His co-worker, while skeptical at first, concluded that the switch was, in fact, dangerous in its current, almost completed, configuration. Furthermore, his co-worker agreed that the new design was probably (not certainly) the cheapest way to remedy the situation.

When the engineer took his results to the site supervisor, they were immediately dismissed. The supervisor insisted that the risk was well within reasonable limits (while the engineer was sure that there was a high probability of injury from the device). When the engineer pressed his case, and did not immediately back down, his supervisor became upset. The engineer was not fired, but was immediately put on mandatory leave (a common precursor to firing in this company). The engineer forgot to mention that his co-worker had agreed with his conclusions, but, after seeing how the engineer was penalized, his co-worker refused to support the engineer to avoid risking his own job.

Case 2. Reducing the Dosage of a Profitable Pharmaceutical David Ames

Protect Pharmaceuticals is one of the largest pharmaceutical companies in the country. They have become a household name and are consistently listed in Forbe's Fortune 500 list. Sam, a young engineer with an MS in Chemical Engineering, was hired by Protect Pharmaceuticals shortly after he graduated. It was his first engineering job and he was very excited because he felt it was a great opportunity to work for such a large and well-respected pharmaceutical company. Sam enjoyed working for Protect and quickly made his way up the corporate ladder. He was soon part of the research and development team. He was working in the lab developing new pharmaceutical drugs to be sold by Protect. It was his dream job and he was getting paid a very high salary. Sam's lifestyle had changed lot since he started working for Protect. He was living in a big new house and his wife was pregnant with their second child.

Sam was very excited about work. He felt that he was making some new and exciting discoveries. He was working with one of Protect's existing drugs and had synthesized a new pharmaceutical drug that would outperform the latter. This new and improved drug would lessen the dosage from three times a day to two times a day. It would also cut the duration time from five weeks to two weeks. And the effectiveness of each drug would almost be identical. The best part was that it would cost the same to produce as that of the existing drug . Much to Sam's dismay the new drug was rejected by upper management for the reason of lack of research. San strongly disagrees with their decision. He pursued the subject further but got nowhere. He felt that many people would directly benefit from the drug and could not understand why Protect did not want to pursue it further. From talking to other employees Sam was advised to forget about it and move on to other things. That it was just the way things have always been. Co-workers tell him not to cause problems because he is well liked by management and it would be a bad career move. Sam decided to put aside his differences with Protect management and move on to other projects.

A few weeks later a fellow employee confides in Sam that the real reason Protect rejected his improved drug was solely based on money. That they would be losing a considerable amount of money by producing and selling drugs that worked too well. If people need a five week supply of a pharmaceutical drug to get well then Protect is making a lot more money compared to if only two week supply is needed. Sam researches into this theory more and concludes that his co-worker is correct. He is now left with the dilemma of what to do next.

Case 3. Developing the "Particle Replacer" Scott Holloway

When I was young, my mind boiled with ideas. I dreamed of engineering what I thought of as the "particle replacer," or object replicator. Taking a hint from *Star Trek: The Next Generation*, this invention would scan any object that one may have; say, a gold ring. From the “raw materials“ bin of the device it would use the raw material (e.g., dirt) that is given an exact copy of the same gold ring would be produced. This device would actually (and through some way that I've not yet developed!) manipulate the very fundamental electrons, protons, neutrons of the "raw" matter and place them in such a manner as to make an exact copy of the original item (the gold ring).

In my youth, I reveled in thoughts of how marvelous life could be. One of my first ideas was that my mother would just have to make a few tasty dishes and then I could have tasty, homemade food whenever I pleased. The dishes that I always dreaded cleaning could just be dumped into the " raw materials " bin and new shiny, pristine dishes would emerge at the other end. Such a device would be indispensable! This idea swim in my head for a few years, and then age brought a few more ideas. All of the smelly, grotesque landfills could be converted into a pure mixture of atmospheric air. Sewage could be converted into pure water without having the slightest hint of any germs. What an idea! Not only could it save us from household chores, but also from pollution.

And then one day, my mind went too far. Would the proliferation of an object replicator spoil society just as children can be when not told "no"? Would cruel Saddam Husseins and Hitler's get hold of this technology and gain or greatly further their tyrannical control? Such a possibility scared me, and I instantly concluded that this technology could only be released in a far more disciplined society than ours. More recently, I've thought of other possible problems. Would greedy, or over ambitious business executives, grab hold of this technology and fill the world with their product and wipe out the rest of the market? Would this same thing - harnessed in various product markets - stop poverty because of basic needs possibly more easily met, and/or collapse the economy because of things having no worth? Or would an astronomically greater divide result between rich and poor, with the rich being the only ones to use such technology?

The intellectual intent of this assignment was to get the students to see how their own initial approach to a moral dilemma would differ from that of others, and what would be involved in working as a group to resolve it. The final presentations were, in fact, quite impressive, and clearly showed highly interactive group involvement in a nuanced, thoughtful, sophisticated way. In the early stages of the class, it had been evident that when faced with an ethical dilemma, the majority of the students exhibited a strong tendency to prefer following the rules of the company and deferring to the decisions made by management. By the end of the course, the majority of the students were much better equipped to identify and think through the pieces of the case studies they were given and discuss the relevant considerations and difficulties involved. In addition, over the course of the semester, most of the students made significant improvement in these areas through their written and oral presentations.

The students, the invited speakers, and the faculty attending the classes, the professor, and the teaching assistants all felt that the class was a "success." Speakers felt that student questions were insightful and showed, not only technical insight, but also insight into the ethical dilemmas they face as engineers. The faculty felt that the combination of ethical theory woven into case study was highly successful for advanced student learning. The professor and the teaching assistants found the students to be bright, energetic, and genuinely engaged in the issues explored in the class. Finally, the students felt that the course was helpful to them and they were particularly happy with the guest lecturers and the classroom discussions. Student comments included:

- The variety and expertise of guest speakers was quite beneficial in making connection to existing "real world" engineering dilemmas.
- …in-class discussion was very helpful.
- Guest lectures were excellent.
- Class discussion of cases presented in class helped me understand basic ideas taught.
- …I learned a great deal more than I expected to. The things I learned will be very helpful in the future.
- …It (the class) changed the way I see things and the way I should do things…

Conclusions

Overall the course was a success. The advanced-level ethical skills helped students approach problems from various viewpoints and develop arguments to "defend" an ethical stance. The TAs will now work on incorporation of ethical modules into senior-level coursework to build upon these skills.

Next time the class is taught, several improvements are envisioned. First, a norm will be developed for student presentations. Second, more time will be devoted to gender issues. As it was, only one female student was in the class. However, several departments have started a discussion of requiring this course of their students, or at a least, adding this course to the list of strongly-recommended options for General Education; this is sure to change the gender distribution in the class. In addition, to accommodate these students, discussions are underway to see if the course should be offered both semesters. Finally, the College of Engineering will actively recruit students from Science and Business to take the course as a Humanities course in their University General Education requirements. It is felt that a broad distribution of disciplines will also aid in the discussion and interaction, since many students will encounter various disciplines in their workplace as well.

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