Session

AN INSTRUCTIONAL MODULE FOR ENGINEERING ETHICS

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Abstract—This paper describes a short (3 class-hour) module developed to teach engineering ethics. The module has been designed for simple integration into a standard technical course, minimally impacting existing curricula and effectively introducing the need for engineering ethics, the key components in an engineering code of ethics, and resources for help in resolving ethical conflicts. Case studies are used, showing directly how certain ethical issues relate to the practice of engineering and prompting lively in-class discussions. Using cooperative and active learning techniques, the class develops its own code of engineering ethics and compares their code to the professional society codes within their discipline. Test data shows that after taking the module, students are more capable of stating the key components of an engineering code of ethics and are more knowledgeable concerning resources available for resolving ethical dilemmas. Testing also shows that the students have a high awareness of the issues involved in engineering ethics and that, after taking the module, they are significantly more confident concerning their ability to address ethical conflicts in their future professional practice.

Index Terms—ethics, case studies, professional responsibilities, societal impact.

Introduction

An engineer's work can have significant impact on society; therefore the practice of engineering carries certain obligations and responsibilities. Engineers need to assess both positive and negative impacts of particular engineering solutions, to inform society of these impacts, and to gain informed consent before a particular solution is implemented. Engineers need to act ethically, to recognize and resolve potential conflicts of responsibilities to society, to employers, to fellow workers, and to self. Academic institutions, engineering employers, and accreditation agencies are all recognizing that these societal and ethical responsibilities need to be included within the engineering curriculum, along with the traditional technical material. ABET now requires that the engineering program of an accredited institution must demonstrate that their graduates have "an understanding of professional and ethical responsibility [Criterion 3(f)]" [1].

To address this need, we have developed and tested a short (3 class-hour) module on engineering ethics. This module has been designed for simple integration into standard technical courses, effectively introducing key concepts and promoting student awareness, showing directly how ethics are incorporated into the practice of engineering, and minimally impacting the existing curricula. This paper provides details of our module – objectives, outlines for each class, in-class exercises, assignments, assessment guidelines, and techniques for bridging the material into specific engineering disciplines. We have tested our module on a group of students, and the data from our tests show that after taking the module, students are more capable of stating the key components within an engineering code of ethics and are more knowledgeable concerning resources available for resolving ethical dilemmas. Testing also shows that the students are significantly more aware of the issues involved with engineering ethics and have increased confidence in their ability to address ethical conflicts in their professional practice.

Objectives and Structure of the Module

We developed a series of seven objectives for the engineering ethics module. Students completing the module should be able to do the following:

1) Discuss an engineer's professional responsibilities.
2) Discus various engineering ethics codes.
3) Discuss the importance of engineering ethics in the career of an engineer.
4) Discuss the need for a professional code of ethics.
5) Discuss what an engineer should do when the employer's interest conflicts with the public.
6) Discuss resources and contact points that would be helpful in dealing with ethical dilemmas.
7) Given a scenario, identify ethical concerns, describe the appropriate behavior, and discuss the ethical basis for these choices.

We structured the module to require 3 one-hour classes plus appropriate homework and out-of-class groupwork assignments. Limiting the number of required classes allows the module to be more easily incorporated into existing courses, but also limits the depth and/or breadth of topics

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which can be discussed in class. We selected a case study approach with in-class discussions. We chose this structure for our module rather than traditional lecturing, group activity, student presentation, or role-playing, because we felt that with proper guidance from the instructor, this approach might provide an opportunity for more diversity of views, livelier interaction, and more critical thinking. Case studies also show directly how certain ethical issues apply to the practice of engineering.

The module is organized into three 50-minute in-class instruction periods, and students are organized into 3 or 4-person groups for their out-of-class assignments. The first class period is devoted to a case study of the Ford Pinto. During the second class period the students develop their own class-wide code of engineering ethics and then compare it to the various codes within their engineering discipline. The third class period is devoted to a case study of Werner von Braun. Details of the individual class periods, including corresponding out-of-class work, key points for each of the case studies, and an organizational framework for engineering codes of ethics is given in the sections below 3

Case Study #1 – The Ford Pinto

Prior to the first session, students are placed in 3 or 4-person groups and are assigned to read [2 - 4], view a QuickTime movie showing a rear-end collision with a Pinto and the subsequent fire (accessible through [2]), and discuss the following series of questions within their groups:

1) Is it ethical for a company, such as Ford, to perform cost-benefit analyses when lives are involved?
2) As a society we often perform cost-benefit analyses involving lives. For example, we do not require overpasses to be built at all railroad crossings, even though we know that an occasional fatal collision will occur if we do not. How is this different from what Ford did?
3) Do you think that the public was adequately informed concerning the dangers of the Pinto?
4) Could it be possible that upper management at Ford did not understand the engineering issues involved? What was Lee Iacocca's technical background?
5) Suppose you are an engineer at Ford and you have just discovered the Pinto's gas tank problems. You discuss the situation with your manager and he tells you he doesn't see a problem. What, if anything, do you do next?
6) Ford designed the Pinto to satisfy all then-existing legal requirements for safety. Do they have a higher obligation? Does it matter that, during the design, Ford was successfully lobbying the US government to not impose more stringent safety requirements?
7) Should a profession impose ethical obligations which are more stringent than legal obligations? If so, why? If so, how should they be enforced?

In order to ensure that the students read the material and discuss the questions prior to the first class, the instructor may announce that he/she will be giving a short quiz at the beginning of the class period. A sample quiz is included in the instructor's guide.

During the class period, the instructor leads the class in a discussion of the above questions (the instructor's guide provides a large quantity of information and helpful comments to assist the instructor in guiding the class discussion). The questions are designed to elicit the following key points and address the indicated course objectives:

a) An engineer has a responsibility to employ reasonable engineering practices concerning the safety of the products he or she develops. (Objective #1)
b) As a society, we elect to take certain risks because of the possible benefits we may gain. For example, we choose to have a 70 mph speed limit on highways rather than drive at 20 mph, which would reduce the number of accidents, because the higher speed limit allows us to reach our destinations much faster. The key to society taking these risks is that the members of society give an informed consent. (Objectives #5 and #7)
c) Because of their technical background, engineers are more likely to grasp the possible societal and safety implications of a technology or a product than either company management or the general public. An engineer has the responsibility to inform management of possible safety hazards in products he or she is developing. If management does not respond appropriately, the engineer has a responsibility to work within her/his company to make sure that his/her concerns are known and given due consideration. The engineer may also have a responsibility to inform the public (i.e., to blow the whistle). (Objectives #4 and #7)

3 Interested readers can preview all material for our module, including the instructor's guide, assignment sheets, and appropriate audiovisual material at http://www.ece.ua.edu/faculty/pimmel/public_html/ec2000-modules. Electronic copies of the module material are also available by directly contacting the authors. The above URL provides previews for a total of 15 modules developed by various educators as part of the Foundation Coalition, with support from the Engineering Education Program at the National Science Foundation under award number EEC9802942. The other fourteen modules are computational skills, design skills, experimental skills, modeling skills, societal impact of engineering, knowledge of contemporary issues, problem solving, project management, lifelong learning, teaming, time management, graphical communication, oral communication, and written communication.

d) Engineers have ethical responsibilities concerning the public's safety which are more stringent than legal obligations. The technical complexity of issues within our profession, coupled with rapid changes in technology, mean that the public cannot be protected through explicit laws alone, since the laws cannot always be current enough or provide sufficient detail to handle all relevant situations and still encourage responsible innovation. Development of and adherence to a professional code of ethics is therefore necessary. Enforcement of the code is often accomplished through peer pressure and a civil court system which uses professional peers to advise juries concerning reasonable engineering practices. (Objectives #5 and #7)

Additional concepts include an engineer's responsibility to his or her employer, gauging a company's culture to determine its commitment to public safety, and determining when whistleblowing is acceptable or even imperative.

There are many safety-related cases which are newer than the Ford Pinto (in particular the cases of the vulnerable Chevy S10 saddlebag-style gas tanks and the problems with Firestone tires on the Ford Explorer), and these newer cases may be more familiar and feel more contemporary to the students. Nevertheless, we chose the Ford Pinto case because it has the following unique features.

1) The cost-benefit analysis was clearly spelled out and explicitly performed. In an internal memorandum, Ford used a $200,000 per life lost figure (from an NHTSA study) to justify not repairing the problem. Students should at first be appalled that such an analysis was performed, then, through discussion of the first and second questions above, they should see that as a society we often perform cost-benefit analyses involving lives. Differentiation between a company analysis and a societal analysis should help students understand the societal impact of engineering, to appreciate the need to inform society of the technical consequences of various engineering solutions, and to gain an informed societal consent prior to implementation.
3) Upper management at Ford, in particular Lee Iacocca, had a technical background (Bachelor's in Industrial Engineering from Lehigh University, Master's in Engineering from Princeton). This robs the student of any comfortable feeling that the problem may only have occurred because management did not understand the technical issues or have the training necessary to perform a sound scientific assessment. The instructor should still note that in many cases management does not have a technical background and that part of an engineer's ethical responsibility is to make sure that management understands the technical issues.
4) The purely legal mechanisms of regulation and the criminal justice system were both used in the Ford Pinto case, and were insufficient to safeguard the public. As part of the pre-class reading assignment, students are informed of the State of Indiana's negligent homicide trial of Ford[4], which ended in acquittal, possibly due to the high burden of proof rightfully required in a criminal proceeding. As also discussed in the assigned pre-class reading (and in Question #6), establishment of regulations is a slow, drawn-out procedure which can be either insufficiently responsive to safeguard the public or else can be over-encompassing and stifling to responsible innovation. The Ford Pinto case shows that criminal law and regulations alone are inappropriate to balance the public's interests in safety and responsible innovation, hence one of the needs for ethical obligations.

Developing a Code of Engineering Ethics

This second session addresses Objectives #2, #4, and #6. As a pre-assignment for the second session, each student group is tasked with developing its own engineering code of ethics. The students are specifically told NOT to read any professional organization's codes prior to doing their work, but to develop their own codes based on the first session's case study (concerning large, societal issues) and based on their own experiences (concerning smaller,

4 The following paragraph is included in the student's reading assignment:
"Some legal background: Most of the lawsuits against Ford were civil suits for actual and punitive damages, but one case involved criminal charges. In Indiana a rear-end collision between a van and a Pinto caused a fire which killed three teenage girls in the Pinto. Ford was subsequently tried in Indiana on the criminal charge of negligent homicide (this is the trial mentioned in the … web page). There were no accompanying civil suits for this particular incident because, at the time, Indiana law severely limited the amount of damages which a parent could recover for the death of a minor child (no punitive damages were allowed and actual damages were limited to the lost wages which the minor might have earned in the time between his/her death and age 18). Many argue that Ford was acquitted of the negligent homicide charge because the standard of proof in a criminal charge is much higher than the standard of proof in a civil charge (reasonable doubt vs. a preponderance, or balancing, of the evidence). The most damaging civil case against Ford was *Grimshaw vs. Ford*, a California case in which a jury awarded $150 million in punitive damages (later reduced to $6 million on appeal)."

personal issues). During the second session the instructor leads a 35-minute discussion to develop a class-wide consensus for a code, using contributions from each group. The instructor then summarizes the discussion, noting that all the suggested items can be divided into classes of responsibilities — responsibilities to society, to an employer, to fellow workers, and to self, and that ethical problems arise when there are conflicts between responsibilities to two or more of the above classes. These observations provide a general structure for ethical codes and give students a way to analyze and resolve ethical problems. The instructor then provides copies of ethical codes from appropriate professional societies, reinforces the observations about how codes are organized, and relates the professional society ethical codes with the code developed in class. The instructor also discusses resources (professional societies, web pages, journals, books, and hotlines) which can help engineers when they are confronted with particular ethical issues (these resources are listed in the instructor's guide).

Case Study #2 – Werner Von Braun

The third session is a case study involving Wernher von Braun, with students having read a series of web pages and a book review [5-12] as their pre-class assignment. The first few web pages praise von Braun's technical achievements and downplay his involvement with the Nazis during World War II. Later web pages discuss his joining the SS, his knowledge of the concentration-camp-like conditions at the facilities where the V2 rockets were produced, and the damage to civilian population centers caused by the V2. Taken as a whole, the web pages attempt to balance von Braun's actions during World War II with his post World War II attitude and his work at NASA. After completing their reading, the student groups are asked to discuss the following questions among their members prior to class:

1) What do you believe motivated von Braun to work for the German military (as early as 1934)? Do you think that Von Braun believed in the Nazi cause?
2) What do you believe motivated von Braun to come to America after the war? Do you think that von Braun had patriotic feelings for the US?
3) Consider Tom Lehrer's lyrics concerning von Braun [9]:
   "Don't say that he's hypocritical
   Say rather that he's apolitical
   'Once the rockets are up who cares where they come down?,
   That's not my department,' says Wernher Von Braun"
   Do you believe these lyrics are an accurate assessment of Von Braun's attitudes?
4) Do you think it is ethical for an engineer to develop a product (or technology) and not care how it will be used?
5) What do you believe motivated Von Braun to work for the Nazis and then come to America?
6) Comment on the use of slave labor at Pennemunde. Needless to say, this is an extreme case, but do you believe that an engineer has any responsibility for ensuring safe and humane working conditions for laborers and co-workers?
8) Do you believe that an engineer or scientist's technical contributions should be assessed independently of his or her behavior?
9) Do you believe that history has fairly judged Von Braun?
10) Do you believe that the US government acted ethically concerning Von Braun?

As with the Ford Pinto case study, the instructor has the option of giving a short quiz at the beginning of the class period.

During the class period, the instructor leads the class in a discussion of the above questions (again, the instructor's guide supplies additional information). The questions are designed to elicit the following key points and address the indicated course objectives:

1) An engineer's work can have a very significant impact on society. (Objectives #1, #3, and #5)
2) It is unethical for an engineer to develop a product (or technology) not caring about how it will be used or about its impact on society. An engineer cannot divorce himself or herself from the societal impact of his or her work. [Note: There is much evidence to support an argument that von Braun did not sufficiently care how the technology he helped develop for Germany was being applied. The class discussion produced here, of course, will not definitively answer the question of von Braun's motivations and concerns, but it should be able to use arguments on both sides to address the larger issue.] (Objectives #1 and #5)
3) It is unethical for an engineer to exploit unfair labor conditions to develop a product or technology. (Objectives #1 and #5)
4) Society and history will often credit an engineer for his or her technical accomplishments without holding the engineer responsible for his or her behavior. Such "hero-making" is wrong. (Objective #1)
5) Governments can behave unethically. This does not excuse unethical behavior on the part of the engineer. [Note: This issue needs to first be addressed in the context of the ethics of the Nazi government. If the instructor wishes, she or he can also focus the question on the ethics of the post-World War II U.S. government, about which there is considerable controversy and honest difference of opinion, particularly when one views the events in the context of the Cold War. If this issue is examined, the instructor needs to remind the class that the purpose of the ensuing class discussion is not to definitively justify or condemn the government's actions toward von Braun, but rather to use arguments on both sides to address the larger issue.]

6) Ethical mistakes can compound. You can start with a small error in judgement which will later precipitate a larger error in judgement, etc. The way to avoid the “slippery slope” is to make proper ethical judgements in the first place. (Objectives #1, #3, and #7)

Wernher von Braun is an especially good case study for students here at the University of Alabama. Many of our students co-op in Huntsville, where von Braun worked for the NASA Marshall Space Flight Center.

Increased Confidence

In an evaluation program, we taught the engineering ethics module in a classroom setting with a faculty member, other than the developer, as teacher. The module was taught during a standard 50-minute period on a Monday, Wednesday, and Friday schedule to ten students[5]. The students were randomly selected from a group of paid volunteers after screening for schedule conflicts. The overall group contained 65% seniors, 25% juniors, and 10% sophomores. In this population, 45% had a GPA above 3.0 while 55% had GPAs between 2.0 and 3.0; 61% had one or more coop or intern experiences, while 39% had none. In response to a question about their formal training in engineering ethics, 48% indicated that they had no experience, 36% indicated experience in one or two classes, and 16% indicated experience in three or more classes. Before teaching the module, we asked the students to assess their confidence in their ability to complete tasks representative of the module’s learning objectives (listed on the first page of this paper). We created a list of statements and asked the students to indicate their confidence for each statement using a five-valued scale (i. e., 1 – “*Strongly Disagree*”, 2 – “*Disagree*”, 3 – “*Neutral*”, 4 – “*Agree*”, and 5 – “*Strongly Agree*”). We created the list of statements by converting each learning objective into one and only one task statement so that there was a one-to-one correspondence between the modules’ learning objectives and students’ confidence statements. For example, Objective #3, *“Students should be able to discuss the importance of engineering ethics in the career of an engineer”* became *“I am confident that I can discuss the importance of engineering ethics in the career of an engineer”*. After the module was completed, students were again asked to rate their confidence in being able to achieve each of the module’s objectives.

The data for the ethics module is given in Table 1. The numbers in the first column correspond to the numbering used to list the module’s objectives on the first page of this paper. For example, in their pre-module test, the students gave a 3.4 rating to the statement “*I am confident that I can discuss resources and contact points that would be helpful in dealing with ethical dilemmas*”, corresponding to Objective #6. Table 1 shows a significant increase in the students’ confidence to achieve each objective of the ethics module.

TABLE 1. PRE- AND POST-MODULE CONFIDENCE IN ACHIEVING ENGINEERING ETHICS OBJECTIVES

Objective	Premodule	Postmodule	Improvement
1	3.5	4.4	+ 0.9
2	3.2	4.5	+ 1.3
3	3.8	4.4	+ 0.6
4	3.8	4.5	+ 0.7
5	3.7	4.5	+ 0.8
6	3.4	4.5	+ 1.1
7	3.6	4.3	+ 0.7

Increased Awareness

Students were also asked to assess their awareness of ethical issues by rating, on the same 1 – 5 scale, their opinion of the importance to a graduating engineer of each of the seven objectives both before and after they took the module. As with the confidence measurements, we asked the students to rate a series of questions which had a one-to-one correspondence with the objectives (the question, for example, for Objective #6 was “*It is important that graduate engineers can discuss resources and contact points that would be helpful in dealing with ethical dilemmas.*”) The results, shown in Table 2, indicate that the students had a high awareness of the importance of ethical issues to engineering before the module began, but that the module did not increase their awareness. (Cynically speaking, this advance awareness may simply be due to the student’s advance knowledge of the title of the module.)

TABLE 2. PRE- AND POST-MODULE ASSESSMENT OF IMPORTANCE OF ENGINEERING ETHICS OBJECTIVES

Objective	Premodule	Postmodule	Improvement
1	4.5	4.5	0
2	4.3	4.4	+ 0.1
3	4.4	4.5	+ 0.1
4	4.4	4.5	+ 0.1
5	4.5	4.4	- 0.1
6	4.3	4.4	+ 0.1
7	4.5	4.3	- 0.2

Increased Competence

Using another student group (our Spring 2002 Senior Design class, where the ethics module was taught by the first author) we administered a pre- and post-module test consisting of two questions:

1) Develop a series of guidelines to help an engineer make sure

5 We acknowledge that this is a small group of students, and we advocate further testing.

that he or she is acting ethically in various professional situations.

3) List resources that an engineer can consult if he or she has questions concerning professional ethics.

The first question, specifically left open-ended, was designed primarily to assess our success in achieving Objective #1, and the second question was designed to assess achievement of Objective #6. The post-test was administered unannounced during a class period two days after completion of the ethics module. Fourteen students took both the pre-module and post-module tests.

The tests were graded by a third party, with the pre- and post-module tests intermixed to remove any grading bias (our identifying mark was not visible to the grader). We instructed the grader to examine the responses to the first question and to determine which of the four responsibilities (society, employer, others, and self) were addressed in the student's answer. For the second question, we asked the grader to identify the number of separate resources listed and categorize as zero, one, two, or more than two.

Evaluation of the first test question is shown in Table 3. The module significantly increased recognition of responsibilities to others and moderately increased recognition of responsibilities to society and to self. Recognition of responsibility to an employer was slightly reduced – the authors believe this may be due to the emphases in the case studies. To address this issue, the questions in the Ford Pinto case (and the instructor's guide) are being modified to further stress the engineer's responsibility to try to resolve ethical issues within the company internally before whistleblowing. Table 3 can also be interpreted to show that after taking the module the students better understand the concept of ethical problems arising from conflicting responsibilities – pre-module answers listed an average of 2.07 competing responsibilities, while post-module answers listed an average of 2.57 competing responsibilities.

TABLE 3. PRE- AND POST-MODULE IDENTIFICATION OF CONFLICTING RESPONSIBILITIES

Responsibility	Society	Employer	Others	Self
Pre-module	8	9	3	9
Post-module	10	7	8	11
Difference	+2	-2	+5	+2

Table 4 shows the number of separate resources the students were able to identify for help in resolving ethical issues. Prior to the module, 28% of the students were only able to identify a single resource, but after the module 93% were able to identify three or more resources. We believe that Table 4 shows positive achievement of Objective #6.

TABLE 4. PRE- AND POST-MODULE LISTING OF HELPFUL RESOURCES

No. of Resources Identified	0	1	2	More than 2
Pre-module	0	4	1	9
Post-module	0	0	1	13

Conclusions

We have developed a short, 3-class-hour module for engineering ethics which can be integrated into a standard technical course. The module, which includes case studies and the development of a code of ethics, uses cooperative and interactive learning techniques and effectively introduces the need for engineering ethics, the key components in an engineering code of ethics, and resources available to help resolve ethical issues. The module includes an instructor's guide, which provides objectives, outlines for each class, in-class exercises, assignments, assessment guidelines, and techniques for bridging the material into specific engineering disciplines.

Test data shows that after taking the module, students are more capable of stating the key components of an engineering code of ethics and are more knowledgeable concerning resources available for resolving ethical dilemmas. Testing also shows that the students are aware of the issues involved with engineering ethics and have increased confidence in their ability to address ethical conflicts in their professional practice.

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