Int. J. Engng Ed. Vol. 21, No. 3, pp. 373–377, 2005
Printed in Great Britain.

0949-149X/91 $3.00+0.00

How Best to Inject Ethics into an Engineering Curriculum with a Required Course*

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Engineering students should, in the course of their undergraduate education, learn about the professional responsibilities associated with their chosen profession. They should learn about major technology-society issues involving such matters as energy, war, the environment and privacy. Ways to accomplish this include the incorporation of such ideas in regular engineering courses, occasional colloquium talks, and special courses devoted to this general area. It is argued that, whatever else is done, at least one such course should be required for graduation. Some practical aspects of such a course are discussed.

INTRODUCTION

GIVEN the enormous impact that technology has on our lives, and the importance of engineers in implementing that technology, it is scarcely necessary to argue that engineers should be conscious of their responsibilities, and knowledgeable about the many ways in which their work impacts the lives of others.

How can engineering students best be educated about ethics in their chosen profession? One view is that an understanding of this subject can be acquired only by actual experience in the field. Only when forced to deal with real problems, goes this argument, can people truly appreciate the difficulties and nuances of professional ethics. I agree that there is much truth in this assertion. But one could make similar statements about any aspect of engineering work. For example, one could say that nobody can really understand the difficulties involved in designing a reliable electrical system for an automobile, without being involved in such an effort under real-world conditions. Nevertheless, we teach students all sorts of subjects that put them in a position to deal with the technical problems that they will face in actual practice. Precisely the same argument can be made for teaching about professional ethics. It is certainly reasonable to do the best we can to prepare engineering students to face the ethical, as well as the technical problems that they might encounter.

There is now a general consensus that engineering curricula should include substantial education related to professional ethics. This is formally embodied in the latest ABET (Accreditation Board for Engineering and Technology) requirements for the accreditation of engineering curricula [2]. These require that students acquire certain skills in dealing with ethics related issues. A number of ways to implement such education are treated below, where it is argued that an essential ingredient is a required course. A survey of how US engineering schools have been dealing with this subject is in [3].

OBJECTIVES OF EDUCATION IN PROFESSIONAL ETHICS

In my judgment, the most important concept that should be conveyed to prospective engineers (I use this term to include computer and other applied scientists as well as engineers) is that, as professionals, engineers are personally responsible for the consequences of their work. They cannot properly take the position that they need only carry out orders issued by their managers, delegating to those managers responsibility for the larger aspects of the projects they are involved in. Not only must they be conscientious in carrying out specific assignments with diligence and competence, they must also bear in mind the societal impacts of those projects. They cannot properly suspend their moral judgments when they enter the workplace. Within reasonable limits, there is room for substantial differences of opinion about whether a particular engineering project is, on balance, beneficial. But it is certainly wrong for engineers to work on projects that conflict with their own moral codes. For example, engineers who believe that hard liquor is intrinsically harmful ought not accept assignments to help design whiskey distilleries.

* Accepted 8 March 2005.

A basic precept incorporated in all modern engineering ethics codes is the duty to safeguard the public health, safety, and welfare. This must be made clear to all engineering students.

Engineering students should be taught the need to think beyond the immediate tasks they are assigned on any project. They should be prepared to acquire a general understanding of the larger aspects of projects so that, among other things, they can recognize and deal with interface problems. This is an example of the overlap between good practice with respect to the technical and the ethical aspects of engineering. Another such overlap is the need to convey the importance of attention to detail in their work, particularly where safety is a factor.

Treating people fairly is, of course, something every decent person does as a matter of course. But the cooperative nature of engineering makes it particularly important for engineers, and there are specific aspects of fair play that need to be emphasized in a professional environment. These include, for example, properly crediting others for their work contributions.

Another aspect of general good moral conduct that is especially important for engineers is honesty. Technological enterprises cannot prosper if participants do such things as falsify data, or make commitments that they know they cannot fulfill.

In addition to teaching students ethical principles as outlined above, it is important to ensure that they learn about the principal ways that technology impacts society. They should be exposed to and involved in discussions of such matters as risk management, environmental issues, energy conversion and use, war, transportation, effects of technology on work, privacy, free expression, legal liability, and intellectual property. Students should also learn about how organizations actually operate, and how to conduct themselves in situations where they are in conflict with managers.

MECHANISMS FOR TEACHING ETHICS

Apart from specific courses devoted to this material, which will be discussed in later sections, there are a number of ways that professional ethics topics can be introduced into the engineering curriculum. These entail various degrees of participation by engineering faculty.

A simple, low cost, approach is to distribute to students copies of appropriate engineering ethics codes, and to post such codes prominently in hallways, classrooms and laboratories. A minor elaboration would be to do the same with short written essays on various ethics-related topics. Pointers to websites with more elaborate items can similarly be posted.

Occasional special colloquia might be held, with invited speakers, or, where departments have regularly scheduled colloquia open to all students, topics pertinent to engineering ethics might be included, perhaps once a semester. Student branches of engineering societies might be encouraged to schedule meetings devoted to this subject. Some engineering departments (or schools) have 0-credit orientation courses for entering students, that introduce them to the engineering field. This is a natural place to include a module on ethics.

Individual faculty members can contribute to ethics education in a number of ways. One is to comment on ethical issues in conjunction with various technical topics. For example, when discussing fault-detection techniques in logic circuits, I customarily point out the need for this and the fact that there are occasions when, due to the pressure of fixed delivery dates, managers sometimes try to cut corners on testing. I suggest that it is necessary for engineers to resist such pressure when serious risks are involved.

Some instructors, when teaching courses that inherently involve important societal issues (for example privacy is often an important factor in database systems) devote entire lectures or even sets of lectures to particular ethical issues. They sometimes invite people with special expertise to give one or more of these lectures.

For many years, it has been my practice in all my courses to devote the last twenty minutes of the final lecture to a survey of ethics in engineering. Since some students are exposed to two or more such mini-lectures, I take care to vary the details treated.

Many engineering departments include in their curricula capstone design project courses for seniors [NICHOLS]. These attempts to simulate real engineering problems often include, in a very natural manner, discussions of ethical issues. A complementary approach, which merges ethics with a freshman-level programming course is described in [1].

Apart from ideas as above which can be implemented internally by engineering departments, all engineering curricula include substantial numbers of nontechnical courses, many of which are electives. These are intended to broaden the perspectives of the students. Many of these can contribute to ethics education.

A SPECIAL COURSE

Another approach, not inconsistent with those sketched above, is to have one or more courses specifically designed to meet all or most of the objectives. In most schools such courses are electives, but some schools, or departments, require students to take at least one such course. (Arguments on this are presented below.) These courses are of various types: some focus very precisely on the subject of engineering ethics, while others are more broadly aimed at the area of technology and

society, with engineering ethics as one of a number of topics. It is the latter type that I will treat here.

For over thirty years I taught a course entitled, 'Technology and Society', which covered all the material mentioned above. (For a smaller number of years I taught a more specialized course of the same type, entitled, 'Computers and Society'.) This course was an elective for all engineering undergraduates. Most of the course was about societal issues such as energy, war, privacy, etc., with an important component being engineering ethics, professionalism and the handling of intra-organizational problems. I made heavy use of real ethics cases to illustrate graphically the ethical dilemmas sometimes faced by engineers.

I used, at different times, a variety of books on the societal issues, along with my own book on engineering ethics [5]. These were supplemented with (usually current) items placed on reserve in the library. A lot of good material is now easily accessible on the Internet. A particularly valuable Internet resource, which not only incorporates a good deal of interesting material in its own space, but which also directs people to other useful sources, is the Online Center for Ethics in Engineering and Science. (www.onlineethics.org).

My Technology and Society course was deliberately conventional in form, with written exams and a term paper. An important concern was to ensure that students understood that they would have to do the reading and study if they were to get by. Given the heavy loads carried by engineering students, my assumption was that even the most conscientious students would begin skipping classes and not studying if they thought they could get away with it. I found that it was useful to give two shorter exams in place of one midterm exam (in addition to a final exam), because the students did not have a good feel for what exams in such a course would be like. I included both short answer questions, usually of a factual nature, and essay questions on each exam. My grading for the course was, as is my grading in other courses, not lenient.

Students were given a list of suggestions for term papers, but had the option of choosing some other topic. I had them write one-page proposals for the term papers, which I reviewed and returned with suggestions. While in many such courses, students give presentations to the class on their term papers, I did not see how I could do this because of scheduling problems.

There are a number of techniques that are used in such courses, which I am sure are often valuable, but which, for one reason or another, I never tried. One is role playing, which I think may be very useful when discussing ethical problems. I also never used visual aids, or video tapes. These too may indeed be useful under certain circumstances.

Class discussion is a vital part of such a course. (Actually, I feel that it is very important in *all* courses.) I made every effort to encourage it, with moderate success. Of course a key factor is to treat students with respect and to make it clear that they can speak frankly despite their viewpoints.

Perhaps the most difficult part of teaching such a course is the need for great care in handling controversial issues—which includes most of the material discussed. An important course objective was to get the students to understand, and to be able to restate, the arguments on various sides, regardless of their own positions. Since I had strong opinions on most of the controversial matters considered, and did not think it appropriate to conceal them, I did the best I could to present opposing arguments fairly. College students are adults, they are eligible to vote, and presumably are able to think for themselves. Nevertheless, the instructor is an authority figure and has real power over them. Therefore, I strongly encouraged students with different positions to present them. In grading essay questions and term papers, and in assigning course grades, I bent over backwards to favor those whose views conflicted with mine, in an effort to compensate for subconscious bias.

Almost all the students who elected my course were engineers, but there were a few liberal arts students, most of whom did quite well. I think it is important that such classes consist predominantly of engineers, so that they can be comfortable discussing problems involving their chosen profession. There were two types of students who elected my course. One consisted of those with some prior interest in the subject. The other, probably larger, group, consisted of those who were looking around for a course that happened to fit their schedules. It was particularly satisfying that many in the latter group developed a real interest in the subject.

Class sizes varied considerably, ranging from around 15 to perhaps 45, most often in the low twenties. I feel that classes in excess of about forty are too large, because of the burden of grading term papers and essays questions on exams, and because any particular student is less likely to participate in class discussion when the group is larger.

I feel that there is great value in having a course such as the one described here taught by a regular member of the engineering faculty. This contributes significantly to the idea that societal concerns and professional ethics is an integral part of engineering, not some peripheral topic. It helps too if the instructor has had some experience in industry as it again makes the subject more real. Having said this, I must also add that there are many excellent courses of this type taught by philosophers or other non-engineering faculty. As in many cases, the quality of the person is more important than any formal credentials. There are also schools where such courses are taught by two people, one an engineer and the other somebody in the field of liberal arts or a social science.

THE IMPORTANCE OF A DEDICATED COURSE

Each of the ideas mentioned can be useful in educating engineering students about the ethical aspects of their chosen profession (even those who are pre-law students can benefit). Those methods can be used in combination—the more implemented the better—and there is certainly no conflict between using those methods and also having available one or more dedicated courses as discussed. However, I feel strongly that allowing engineering students to graduate without ever having taken a course in the general area of technology and society is a mistake.

I can imagine a situation in which all the objectives outlined above could be achieved without a dedicated course being taken. But, as a practical matter, I doubt that it could be achieved in any existing situation. No doubt some of the important topics might be covered as parts of various regular engineering courses, but many other topics don't fit into that framework. One such topic is that of how to disagree with management and have a hope of prevailing—or at least surviving. Basic philosophical issues such as the extent to which one should risk one's career in order to protest a dishonest act by one's employer are hard to deal with on the fly. Handing out reading material or URLs won't do because participation in real discussions is an essential part of the learning process. Any one of these topics might be the subject of a colloquium talk, but such events are also not conducive for in-depth discussions.

I believe that relatively few engineering faculty members are knowledgeable about engineering ethics—a reflection of the poor state of education in this area in the past. Most feel hard pressed to cover the core material in their courses, which is often evolving at a great rate. Arguing, as some do, that engineering ethics is 'too important to relegate to a single course—it must be embedded in all our courses', leads to the 'everybody's business is nobody's business' pitfall.

Elective technology and society, or engineering ethics, courses are certainly useful, and are, of course, better than nothing. But, since only a fraction of the students will elect them, they can't do the job. Furthermore, the absence of a required course in this category delivers a clear message to the student: 'This subject is less important than any of the required courses or many of the electives that you may choose to take'.

CONCLUSIONS

Engineering ethics should be an important part of the undergraduate engineering curriculum. It would be ideal if all faculty members included ethics-related material in their courses, but the likelihood of anything close to this happening is small. Furthermore, the distributed approach is not conducive to in-depth discussions by students of basic issues. So, while we should do the best we can to encourage faculty members to incorporate ethics-related concepts in their courses where appropriate, we should also develop courses specifically designed for engineering students, and at least one such course should be a required course.

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