Once upon a time, less than a third of a representative sample of U.S. engineering educators considered the study of differential equations to be necessary for an engineer’s education. When the Society for the Promotion of Engineering Education surveyed over 500 teachers of engineering during the 1920s, it found that only 29% of the instructors believed that differential equations were of primary importance in the standard engineering curriculum [1].

Is Engineering Ethics Optional?

Karl D. Stephan
Needless to say, times have changed. Engineering is now vastly more sophisticated technically than it was eighty years ago. All engineering students must now study differential equations, because the profession now considers a person with no understanding of differential equations to be ill-equipped for modern engineering practice.

Engineering schools in the U.S. stand today in relation to the teaching of engineering ethics in much the same way that they stood in relation to the teaching of differential equations in the 1920s. Judging by the requirements of current U.S. engineering curricula, engineering ethics is a valuable elective, perhaps, and a course that should be required in some disciplines, but by no means all.

In the engineering world of the future, a sound understanding of the theoretical and practical sides of engineering ethics will be as necessary to the proper education of engineers as a knowledge of differential equations is today, if not more so. While there may have been reasons to neglect engineering ethics or treat it superficially in the past, those reasons are no longer valid. I support this assertion with three arguments:

1) Engineering ethics is now a mature, practical academic discipline whose practitioners deal primarily with real engineering cases, not just abstract philosophical theories;
2) Engineering work is now more complex than ever, and its ethical, social, and cultural effects can no longer be dealt with on the “seat-of-the-pants” basis that sufficed when engineered systems were simpler;
3) While most engineering students come to college with a working understanding of general ethical principles already, they need classroom practice to understand and deal with the complex and subtle issues of professional responsibility in engineering before they encounter ethical problems in the real engineering world.

To show that the teaching of engineering ethics is currently not a high priority in U.S. engineering education, I will cite the results of a recent survey.

**SURVEY OF ENGINEERING ETHICS EDUCATION**

In the summer of 1998 I undertook a survey of the published catalog requirements of virtually every undergraduate engineering program in the U.S. The *1996-97 American Society for Engineering Education (ASEE) Directory of Undergraduate Engineering Statistics* lists some 254 programs. I was able to obtain usable catalog data on all but 12 of these programs. The results of this survey were published in the October 1999 issue of *the Journal of Engineering Education* [2]. I will summarize those results briefly here.

The question that formed the core of the survey was, “According to published catalog descriptions, must every engineering graduate of the institution take at least one course whose description states or implies that the subject of ethics is treated?” If as few as one of several engineering programs at a given institution did not require an ethics-related course, the answer for that institution was “no,” even if all other programs did require ethics.

My next step was to categorize the institutions according to ethics requirements. If the answer to the core question for a given institution was “no,” I placed that institution in Category D. If every engineering student was required to take a course whose catalog description mentioned ethics but which did not have engineering ethics as its main focus, I placed the institution in Category C. An across-the-board requirement of one course dealing primarily with ethics put the institution in Category B, and two or more such required courses placed it in Category A. To be generous, I counted required courses in philosophy and religion as ethics-related.

The statistical results are summarized in Fig. 1. Of the 254 institutions listed in the Directory, less than three out of ten had any across-the-board requirements relating to ethics (Categories A, B and C). Since I also counted required courses in religion or philosophy as ethics-related, most of the schools...
with two or more ethics-related courses had historical or current religious affiliations and tended to be small. Partly because of this, when the categories were expressed in terms of the number of 1996-1997 graduates from each institution, the picture was even worse. The survey results indicate that 78% of 1996-97 engineering graduates came from institutions which had no across-the-board engineering ethics requirement.

Of course, the lack of an across-the-board requirement to take engineering ethics does not mean that no one at an institution takes the subject. Engineering ethics, or the closely related subjects of business and professional ethics, are offered as electives at many professional schools, and many engineering students choose to take such a course. Nevertheless, it appears that engineering ethics as a subject is treated by some engineering programs in a cursory fashion, if at all. Anecdotal evidence indicates that most of the programs which require students to take engineering ethics are in civil, environmental, mechanical, or chemical engineering. Departments of electrical engineering and computer engineering are less likely than other engineering departments to require anything more than a few classes on ethics in an introductory freshman engineering course. I will now turn to the question of why engineering schools have avoided facing the challenge of teaching ethics systematically and consistently, and why that challenge must be faced now.

**ENGINEERING ETHICS AS AN INDEPENDENT ACADEMIC DISCIPLINE**

A concern for ethical behavior has been a part of technological activity since the dawn of history. Ancient engineers were often motivated to build well by the threat of heavy penalties for inferior-quality products. L. Sprague de Camp tells the story of how Xerxes decided to invade European Greece in 480 B.C. by means of a floating bridge across the Hellespont (now called the Dardanelles Strait, connecting the Black Sea to the Aegean Sea). Shortly after the bridge was built, a storm came up and blew it away. The engineers in charge were summarily beheaded, and Xerxes recruited a new batch of engineers. History records that the second bridge was a much better bridge [3].

From ancient times until the early nineteenth century, technology was simply something people did. But when an activity becomes the subject of academic study, an important transition has taken place. Much of modern society rests on the foundations of systematic intellectual investigation and codification of knowledge, which is then made available through formal education to all practitioners. Each generation thereby gains the advantage of the experience and knowledge of their predecessors. This kind of thing is so commonplace in industrial societies that we seldom give it a thought, but it is one of the distinguishing marks of modern civilization.

When technologists of the nineteenth century adopted the methods of science and began to codify and publish incontrovertible knowledge about their fields, modern engineering was born. Schools of engineering began to develop, preserve, and propagate engineering knowledge. These efforts contributed to the increased pace of technological change, which has continued to the present time.

There is a distinction between doing engineering in an ethical way, and the intellectual discipline or study of such doing. Someone may be very good at a particular activity – skating, for example, or whistling – and yet be wholly unable to account for how they do it, or why they are so good at it. For most of the history of modern engineering, this is a good picture of how ethical engineering was done. While engineering itself gave rise to an ever-increasing number of technical academic disciplines, the doing of engineering ethically remained simply something that people did, at least most of the time. Except for sporadic efforts
undertaken almost entirely by engineers, no one spent much effort to consider engineering ethics as an intellectual discipline in its own right until about three decades ago.

Vivian Weil has described the rise of engineering ethics as an independent academic discipline [4]. Before about 1975, concern for matters that could be classified as engineering ethics was almost exclusively restricted to the engineering community. The Engineers’ Council for Professional Development (which became the Accreditation Board for Engineering and Technology in 1980) formed a Committee on Principles of Engineering Ethics and conducted a survey on the teaching of engineering ethics as early as 1940 [5]. The engineering ethics education and publications that took place before the 1970s was primarily what historians call “internalist,” meaning that it was done from the viewpoint of those who were working within the confines of the subject of study, namely, engineers.

While valid perspectives can result from such work, the scholarly study of engineering ethics almost always raises historical, social, and philosophical questions. Very few engineers are professionally trained in the humanistic disciplines that are needed to deal with these issues in a way that can contribute to a body of systematic knowledge on which a scholarly discipline independent of engineering can be founded. The types of skills and thought processes needed to study why and how engineers act ethically are often different from those abilities, both technical and nontechnical, which engineers need in order simply to do engineering ethically. But those with humanistic professional backgrounds that qualified them to make such studies first needed to become interested in ethical problems in engineering before anything could happen.

Weil traces the origins of this interest to the post-Watergate era in the U.S. The Vietnam War and the environmental movement also contributed to the force of cultural factors which encouraged academics in philosophy and the social sciences to look for practical problems to address. Engineering ethics turned out to be one of them. The National Science Foundation and the National Endowment for the Humanities encouraged these studies with funding, conferences and journals on the subject began to appear, and by now the field is an established and recognized discipline.

While space does not permit further review of the history of this field, the point I draw from its history is simple. It is that engineering ethics is now the subject of full-time study by numerous professional philosophers, social scientists, and other academics who research and write at the graduate level. This was simply not the case before about 1975. A similar pattern has been followed in most technical disciplines in engineering. Because there are no specialists initially who are trained in new field, those from cognate fields do the early work. Gradually, a number of interested researchers coalesce around the new field and write a few books and articles. If enough interest arises, conferences and journals establish the new field on a firm footing, and eventually graduate students can choose to specialize in the new field, and go on to teach courses and write textbooks in the area. For example, before 1950 there were few if any textbooks or courses on electronic computers. The subject was a rather abstruse specialty taught at only a few graduate schools in the world. As the field gained in commercial and scientific importance, the number of researchers, teachers, and students involved began to increase. Programs in computer science and computer engineering were founded beginning in the 1950s and grew in number and size through the 1960s. Today, the subject has become so fundamental that any U.S. school of engineering that neglects computers in its undergraduate curriculum will not receive accreditation.

In the engineering world of the future, a sound understanding of the theoretical and practical sides of engineering ethics will be as necessary to the proper education of engineers as a knowledge of differential equations is today.

Before about 1975, the lack of good textbooks and a body of scholarly knowledge in the field of engineering ethics was perhaps a good excuse either to neglect the subject in undergraduate engineering curricula or to treat it superficially. For the reasons I have just summarized, this excuse no longer holds water. Engineering ethics is
now a respected academic discipline in its own right. Engineering schools should take advantage of the growing body of practical knowledge in the field by passing it on to their students in a systematic and consistent way.

The relationship between the engineer and his client was often the only relationship in which ethical questions could arise. No great deal of sophisticated academic study was needed to establish right or wrong in the vast majority of engineering cases involving wrongdoing or injury, and the existing legal and professional institutions generally handled what we would call matters of engineering ethics today without considering it as a separate subject. While some early engineering-intensive enterprises were quite large (e.g., railroads and telegraph systems), their hierarchical organizational structure was relatively straightforward and changed slowly. The key features of this early stage of engineering for my purposes were:

1) clearly defined roles for the parties involved: engineer, client, customer;
2) clearly defined and slowly changing organizational structures within which engineers operated; and
3) clearly defined, and generally stable, functions of the physical artifacts produced.

Contrast these early conditions with the state of much engineering today, especially in electrotechnology, computers, software, and related fields. In a five-year period, one engineer may work on two to three radically different generations of technology, each completely superseding the previous one. The engineer’s role may change from technical adviser to manager to publicist from one project to the next.

The recent dot-com boom demonstrated, entire technically-based economies can grow rapidly and vanish almost overnight, taking with them companies, business plans, and organizational structures of many kinds, including engineering ones. If the nineteenth-century engineering environment could be characterized as relatively stable, the twenty-first century environment is plastic or even fluid. Nevertheless, the responsibility of engineers as ultimate technical arbiters has not changed. Today’s engineers face a much greater challenge in determining the effects of their engineering decisions in a vastly more complex and rapidly changing environment than earlier engineers worked in.

Finally, the products of engineering affect more people in a larger variety of ways than ever before, and many of these effects are increasingly difficult for the responsible engineer to anticipate. One reason for this is that highly engineered products travel rapidly throughout the global economy and may be used in cultures that are radically different from the ones in which the product was designed. Another reason is that products themselves, many of them incorporating software, are themselves plastic and malleable to the desires of customers, vendors, and others. The only “software” in a transistor radio was the programming carried by stations within its reception range. In a given geographical area, a radio’s usefulness was limited strictly to enabling one to listen to a certain number of stations. But today’s wireless palm pilots which access the Internet bring the resources of the World Wide Web literally in the palm of one’s hand, with all that this entails. While in a simpler time, it may have been sufficient to rely on an engineer’s common sense and intuition for what uses a product would find, and what potential harm might result, engineers in today’s environment need professional help in making judgments about a product’s uses and effects. This professional help is what education in engineering ethics can provide.
THE NEED FOR PRACTICAL CLASSROOM TRAINING IN ENGINEERING ETHICS

One argument that is heard in opposition to teaching engineering ethics goes something like this: “By the time students are eighteen, their personal ethics are already in place. Nothing we teach them is likely to change that.” This charge is not one to dismiss lightly, but it is an oversimplification of a complex situation.

Most young people who have enough self-control and discipline to gain admission to an engineering program have a functional system of internalized ethical principles already. No one seriously claims that the mind of a college freshman is a tabula rasa, a clean slate upon which professors of ethics may write any moral principles they wish. But engineering ethics is a special kind of superstructure that must be added on to one’s foundation of existing ethical principles in order to fit one for competent and ethical engineering practice. The intent of engineering ethics education is not to build an entire system of ethics from the ground up, but to help the student apply his or her personal ethical principles to situations and problems that are peculiar to engineering.

The classroom is a safe haven where students can make beginner’s mistakes without consequences any more serious than a bad grade on an exam or a laboratory. It is much better for a student’s inexperience to cause the collapse of a software or hardware model of a bridge than it is for a real bridge with real people on it to fall down. That is why engineering students work through practice problems and practice designs, to experience engineering work in the classroom before they deal with it in real life.

Viewed this way, instruction in engineering ethics is simply an extension of this idea beyond the purely technical features of engineering practice. In recent years, ethics educators have found that the case-study approach to engineering ethics introduces students to the complexities and ambiguities of real-world ethical problems in an effective and memorable way. These cases are often taken from records of the National Society of Professional Engineers and other agencies. In studying these cases, students face real-life moral problems, but in a benign environment where time is allowed for contemplation and consideration. Once they have wrestled with a few of these issues in the classroom, they often acquire a new kind of awareness of the ethical implications of technical work. In notes for “The Politics and Ethics of Engineering,” an engineering ethics course that historian John Staudenmaier has taught for many years, he reminds students that the moment of crisis is not a good time to do reasoned, critical ethical thinking:

“... professionals need to think through their own ethical standards before situations arise in which they will have to apply those standards by making choices. The moment of choice is no time to begin figuring out what you stand for...” [6].

Philosopher Michael Davis describes what happens if educators neglect this aspect of engineering:

“... If we limit ourselves to teaching technical aspects of a discipline, those we teach tend to develop a perspective including only those technical aspects. They do not automatically include what we don’t teach. Indeed, they would be quite unusual students even to see how to include such extras. If, then, we teach engineering without teaching engineering ethics, our graduates will begin work thinking about the technical aspects of engineering without thinking about the ethical aspects. They will not dismiss the ethical aspects. They will not even see them” [7, p. 72].

Without formal instruction in engineering ethics, graduates may fall into wrongdoing not out of evil will or malicious intent, but rather out of ignorance and what Davis calls “microscopic vision.” He cites the case of an engineer who was promoted to sales within a power-engineering firm. Soon his manager brought him to meetings where he participated in illegal price-fixing. Because the engineer was so intent on mastering his new job, he failed to see that what his manager and the others were doing was wrong, despite a memo to that effect he received from the firm’s legal department [7, pp. 62, 68-69]. Davis concludes that our present understanding of the psychology of wrongdoing is inadequate to explain situations like this. But if the engineer had encountered a similar situation as a case study in college, he would have at least had the opportunity to form an ethical opinion about such activities before he encountered them on the job.

How can we insure that engineering students get such opportunities without increasing the size of already overburdened curricula? In the following section I will briefly describe plans that several leading schools have successfully implemented in various forms without substantially increasing the overall credit-hour requirements for graduation.

CREDIT-HOUR-FRIENDLY WAYS OF TEACHING ENGINEERING ETHICS

Along with the increased interest in engineering ethics research has come an abundance of textbooks, undergraduate courses, and other aids in teaching the subject to
engineering students. The brief survey of instructional modes that follows is not intended to be comprehensive. Rather, I will give three examples of different ways that various institutions have found to teach engineering ethics without adding a prohibitive amount of coursework to the undergraduate curriculum.

Some schools (such as the University of Detroit Mercy where Staudenmaier teaches) require a single course such as his “Politics and Ethics of Engineering” for all engineering undergraduates. When such a course is taught by a non-engineer, it falls under the category of humanities and can help to fulfill the core or distribution general-education requirements that all undergraduates must meet. In this way, the total credit-hour requirement is not increased by making one humanities course a required one covering engineering ethics.

Other schools such as Drexel have chosen a more integrative approach that combines technical and nontechnical material taught by both engineering and humanities instructors. As Mark Manion and Moshe Kam describe in a recent paper, Drexel faces unusual curricular challenges because of its quarter rather than semester schedule, and its mandatory co-op program which takes students away from campus at irregular times during their stay. Despite these challenges, the Drexel engineering departments worked out a plan which includes instructors from the departments of History and Politics, Engineering, Philosophy, and Literature. In the sophomore and junior years, students take three quarter-long courses for a total of thirty weeks of ethics instruction, roughly equivalent to two semester-long three-credit-hour courses. The topics of study range from professionalism and case studies to readings in fiction and dramatized presentations by students. Manion and Kam believe this system best fits the needs of Drexel engineering students. Their paper also contains a good review of other approaches to the teaching of engineering ethics [8]. While Drexel does not face some of the constraints that make curricular innovations more challenging at larger state schools, they have proved that a comprehensive three-course required ethics sequence can fit within a modern engineering curriculum.

Along these same lines, many other schools take advantage of the presence of science, technology, and society instructors and departments to develop a required engineering ethics course customized for engineering students. Stanford University is one of the better-known schools which requires all engineering majors to take at least one course on the “interaction of technology with values and beliefs, social institutions, or behavior” [9].

Finally, the ultimate in integration is a plan called “ethics across the curriculum.” Similar to the “writing across the curriculum” programs adopted recently by many colleges and universities, this plan insures that problems, projects, and other educational experiences which teach engineering ethics are included in a variety of courses, both technical and nontechnical, throughout the curriculum. While it is not as easy to verify the process of instruction under this plan as it is with stand-alone courses, the new EC 2000 criteria adopted by ABET no longer use identifiable credit-hour requirements as the sole measure of compliance. Instead, other means such as exit interviews and portfolios will be used to assess the effectiveness of instructional efforts in both technical areas and engineering ethics.

Beyond the question of accreditation, however, lies the larger issue of whether it is right to claim that graduates are truly prepared for a lifetime of engineering work with only a superficial understanding of engineering ethics. Unlike more technical skills whose half-life may be measured in years or months, the ability to do engineering ethically is something that can improve with years of experience. As engineering educators, we are obliged to make sure that experience starts where it should: in the classroom, and not on the job.

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REFERENCES


For examples of how to teach ethics across (and outside) the curriculum, see e.g., [10]-[12].