Teaching Engineering Ethics

Bruce Perlman, Roli Varma
University of New Mexico, Albuquerque

Abstract

There is general agreement that engineering students should receive ethics instruction as a part of their undergraduate education. However, there are diverse opinions on how engineering ethics instruction should be carried out. Philosophy of ethics, the original approach, emphasizes normative ideals and abstract principles. The new case studies approach focuses on a number of real and hypothetical cases. This article shows that teaching one approach or the other does not help students become ethical professionals. It suggests bridging the gap between ethical theory and cases by teaching ethical dilemmas and issues that are likely to be encountered in daily professional life.

I. Introduction

Since the late 1970’s, ethics has been increasingly emphasized in engineering curricula. Many programs have introduced elective courses in engineering ethics, whereas others have incorporated modules on engineering ethics in professional ethics courses or included them in technology and society courses. Moreover, the Accreditation Board for Engineering and Technology (ABET) 2000 engineering criteria requests engineering programs to incorporate ethics and ethical considerations in their educational objectives.

There are at least two good reasons for this growth industry in ethics. First, there is a general agreement that the social and ethical issues arising within the engineering profession must be learned like any other form of knowledge. Future engineers can only become reflective practitioners by understanding the consequences of their professional activities on the health and welfare of the public. Second, though learning an engineering code of ethics that holds paramount the safety, health, and welfare of the public is a start, it cannot alone be an adequate guide to practical action. In their daily practice, engineers regularly face the ambiguities and conflicts found among the dictates of technical knowledge, the necessity for capital, and the demands of labor.

Unfortunately, there does not exist an ethics rulebook with hard and fast "do’s and don'ts" which engineers could be taught to follow. Instead, students need to learn to use analytical tools and apply them to experiences necessary for judging the appropriateness of various actions and decisions in their professional life. This requires bridging a gap between abstract ethical theory and rules (including codes of ethics), on the one hand, and case studies, on the other hand.
Merely teaching one approach or the other does not help students become ethical professionals, because norms, rules, or standards alone cannot guide action except in concrete situations and situations without value premises lead to ethical relativism rather than sound decisions. Teaching both approaches together may improve matters, but it does not escape the ambiguity faced in the application to cases of norms, rules, and standards - ambiguities that cannot always be clarified.

In this paper, we propose a focus for engineering ethics courses that we believe overcomes this dilemma. We suggest that faculty teaching engineering ethics pay close attention to those engineering practices that involve decision making on a daily basis. In this manner, students will learn to identify features that are likely to contribute to ethical problems before clear-cut ethical dilemmas emerge.

II. Background

Engineering is an old profession. It began when people started to adapt the materials and forces of nature to meet their needs. However, in the 19th century innovations like the steam engine, the dynamo, the electric generator, the telegraph, the electric lamp, the Gold Rush, steel making, and reinforced concrete radically transformed the engineering profession. The new materials and equipment, the need for efficiency, the economy of design, and an increasing dependence on mathematics and science replaced traditional art and craft within engineering. In its modern connotation the engineering profession represents: (1) expertise, which stems from prolonged specialized training in a body of abstract knowledge; (2) autonomy to make choices which concern both means and ends; (3) commitment to the work and the profession; (4) identification with the profession and fellow professionals; (5) ethics to render service without concern for self-interest; and (6) collegial maintenance of standards to police the conduct of fellow professionals. The American Society of Civil Engineers describes the engineering profession as “a calling in which special knowledge and skill are used in a distinctly intellectual plane in the service of mankind, and in which the successful expression of creative ability and application of professional knowledge are the primary rewards.”

Beginning with the Boston Society of Civil Engineers in 1848, various local and national engineering organizations were founded including the Institute of Electrical and Electronic Engineers or IEEE in 1884, the American Association of Engineers in 1915, and the National Society of Professional Engineers or NSPE in 1934. In the early 20th century, many engineering organizations started developing codes of ethics for their members. The idea behind establishing codes of ethics was to set standards of conduct for members and to enforce these standards. Engineers are supposed to follow the codes of ethics formulated by their professional associations. Traditionally, engineering organizations functioned almost exclusively for promoting the development, application, and exchange of technical information and stressed ethics as gentlemanly conduct. An engineer was to be honest, impartial, avoid conflicts of interest, not criticize fellow professionals, and not compete for commissions on the basis of price.

The 1970s saw increased sensitivity to the negative impact of technology. Issues such as the secrecy of nuclear development, contamination of food and water by the use of pesticides, the increased costs of industrial development and the deterioration of the environment, the Vietnam
War focused public attention. When coupled with the disastrous incidents involving the gas tank of the Ford Pinto and the DC-10 cargo hatch door and engine pylons, these led many engineering organizations to take actions to improve health, safety, and quality of life for people through the positive application of technology. For instance, IEEE created the Committee on Social Implications of Technology (CSIT) to provide a forum for the discussion of controversial matters in its quarterly publication, Technology and Society, and through sessions held at national meetings. Earlier, the general policy of the engineering organizations had been to avoid open discussions of the social and political issues involved in the practice of engineering. Now, engineering organizations take special responsibility for the uses and effects of technology.

Because of the nature of technologies, potential magnitude of their environmental impact, attendant social changes, growing cultural significance, and new concerns about ethical responsibility, education concerning engineering ethics started developing in many engineering programs. Earlier, much of the debate over curricular matters in engineering education centered on giving greater emphasis to the technical courses over the social science and humanistic components of the curriculum. Since the Morrill Act in the 1860s, the average proportion of the curriculum devoted to liberal studies has been reduced from over a year of study to only 15 to 18 credit hours. Furthermore, the goals of most liberal studies requirements for engineering have been to offer general education rather than liberal education specific to the engineering profession. Generally, undergraduate engineering students have been receiving training in basic and engineering sciences, problem-solving methodology, and engineering design, with little emphasis on education in professional or engineering ethics. Elective courses in humanities and social sciences have been confined to issues that fall within the boundaries of those disciplines.

Over the last 30 years, a multidisciplinary field known as Science and Technology Studies (STS) has come into existence in many institutions such as Carnegie Mellon, Cornell, Georgia Tech, MIT, Pennsylvania State University, Princeton, Rensselaer Polytechnic Institute, Stanford, and Virginia Polytechnic Institute. The objective of STS is to provide a platform and valuable set of concepts and theories from the humanities and social sciences for discussion of the role of science and technology in society. STS offers a unique set of courses in the social and cultural aspects of science and technology and of ethics and values. Increasingly, such courses are becoming a part of elective requirements for undergraduates in engineering. In many institutions such as MIT, Stanford, and Cal Tech, the School of Engineering offers courses in engineering ethics, which tend to be cross-listed with departments in humanities and social sciences.

In the 90s, there is general agreement on the value of establishing a link between the social and ethical world and the world of the engineering profession. Increasingly, people have come to realize that engineering codes of ethics alone cannot tell future engineers what to do in specific situations. Furthermore, being a professional engineer does not automatically make a person knowledgeable or practiced in engineering ethics. Also, the ethical aspects of a decision often prove more difficult than the technical. With the ABET 2000’s Engineering Criteria, which requests engineering programs, among other things, to demonstrate that their graduates have “an understanding of professional and ethical responsibility”, engineering ethics courses are likely to grow more in engineering programs.
It should be noted that the private, for-profit sector, the largest employer of engineers, is increasingly looking for those engineers who would not only be more productive, but also understand the social and ethical responsibilities of their profession. Since the 70s, industry has worked under the numerous new regulations for pollution control and occupational health, which have increased the cost of employing technologies. Industry has come to realize that ethics is good business. By being ethically sensitive, companies are seeking to avoid costly situations, to become more marketable though better public relations, to have a partnership with environmentalists, to create a community atmosphere, to show trust and fairness in the workplace, and to make better decisions with free and informed input. In this decade, many major corporations have an “ethics office” to ensure that employees have the ability to express their concerns about issues such as safety and corporate business practices in a way that will yield results and won’t result in retaliation against the employee. Industry prefers to hire engineers who are educated in codes of conduct, liability and responsibility, property rights, and a variety of perspectives including customers, colleagues, government, and the general public. It is, therefore, no surprise that by the 90s, courses related to engineering ethics have increased dramatically.

III. Existing Approaches to Teach Engineering Ethics

Making engineering ethics an integral part of engineering education has not made teaching it easier. Much of the rationale for the implementation of engineering ethics courses has been on new methods of teaching. Most courses have moved away from abstract ethical theory to a case-based approach. Engineering ethics books are filled with popular moral theories, notorious real cases, prepackaged ethical dilemmas, and ethics construction kits. Below, we discuss some major approaches in teaching engineering ethics as well as their shortcomings, before suggesting our approach.

In the beginning, the emphasis was on abstract moral theory. The 2500 years of recorded history of the Western intellectual tradition contains diverse theories of ethics and values. Most engineering ethics books contained a variety of ethical theories to emphasize normative ideals and abstract principles. Martin and Schinzinger’s 1996 book, Ethics in Engineering in its 3rd edition is one of the currently popular books in engineering ethics, and has a theory-based approach. It introduces four major ethical theories: rights, utilitarian, deontological, and virtue ethics. It defines engineering ethics as “(1) the study of the moral issues and decisions confronting individuals and organizations involved in engineering, and (2) the study of related questions about moral conduct, character, policies, and relationships of people and corporations involved in technological activity”.

Since engineers have a special responsibility to the public, which is often expressed in terms of professional ethics, many use key concepts of professional behavior to teach engineering ethics. For instance, one normative framework uses three core concepts: (1) competence – the engineer is a knowledge expert; (2) responsibility – the knowledge has power and must be used wisely; and (3) safety – engineers should be cognizant of, sensitive to, and strive to avoid the potential for harm. Against such concepts the moral behavior of engineers is gauged. Such books discuss the codes of ethics in detail since they believe that there has been ignorance about knowledge of
ethical standards set by professional societies. In this view, a code of ethics provides a framework for ethical judgment for a professional engineer.

Teaching engineering ethics on the basis of moral theories, concepts for professional ethical behavior, and codes of ethics helps students to recognize many problems in society and decide what ought to be done. However, theories, concepts, and codes alone cannot be the sole source for teaching engineering ethics. Being abstract, they are unable to guide students in specific situation. Further, they do not address how a correct ethical decision can be taken, but rather depend on the recognition of ethical problems beforehand to which the rules must be applied. Most importantly, for the reasons stated students find it difficult to apply theory or codes to hypothetical cases or real-life situations. Without bridging the gap between moral theory and codes of ethics on the one hand and real cases and concrete situation on the other, it has been hard to help students to become ethical engineers.

Recognizing problems in the abstract theoretical approach, the new goal in teaching engineering ethics has become to train students to analyze complex problems and learn to resolve them in the most ethical manner. The practical ethics literature in engineering relies on the case-based approach and problem-solving approach as a method for teaching.

The case-based approach views engineering ethics as encompassing the more general definition of ethics, but applying it more specifically to situations involving engineers in their professional lives. For instance, Fleddermann defines “engineering ethics [as] the rules and standards governing the conduct of engineers in their role as professionals”. Harris, Pritchard, and Rabins find “engineering ethics [as] concerned with the question of what the standards in engineering ethics should be and how to apply these standards to particular situations”. The case-based approach picks a number of cases (real and hypothetical) which engineers face or are likely to face such as conflicts of interest, trade secrets, confidentiality, professional responsibility, and public health and safety. It then highlights the ways engineers should conduct themselves in their professional capacity.

The case-based approach has been useful in convincing otherwise engineering faculty and students who believe ethical problems are not really their concern. Many engineers still tend to resist such instruction because they view engineering ethics as having little to do with real life and engineering practice. This attitude stems for the greater part from the assumption that technology is efficient, predictable, logical, rational, value-free, objective, and a sign of human progress. In such situations, teaching engineering ethics through case studies makes students reconsider this positivist philosophy of technology, recognize the negative impact of technology, imagine ethical conduct, and then apply these insights to engineering situations. Moreover, when some cases touch students, they are likely to remember the lessons learned from those cases.

One major shortcoming of the case-based method of teaching engineering ethics might be called the problem of "professional distance". One factor in the creation of professional distance is "scale". Scale has to do with size, impact, and importance of the cases studied. Much of the case-based method of teaching engineering ethics focuses on famous cases such as the Ford Pinto, the Citicorp Center in New York, and the space shuttle Challenger. For most students, who will never work in such situations, let alone be part of such far reaching endeavors, cases such as
these end up maintaining a real distance between engineering practice and ethical considerations. Most engineering students find it hard to believe that they will be a part of a situation that will lead to such great disasters. Professional distance is aggravated further by the factor of "currency" in the cases selected. For today’s students the cases cited above occurred long before these students were born or while they were in kindergarten. These cases are distant in time from their current professional practice as well as distant in scale. Just as important, business and political circumstances have changed since these cases occurred. In addition, professional distance is aggravated further by the factor of "locale" in the selection of cases. For most students, the gas leak at the Union Carbide chemical plant in Bhopal, India, or the nuclear power plant accident in Chernobyl, Russia occurred in far away countries with very different political systems. Simply put, many students cannot relate these cases to their own practical professional situations. Lastly, the case-based method of teaching engineering ethics creates professional distance through the factor of "individualism" in case selection. Most of the cases mentioned highlight scenarios in which either heroic action or no action by individuals occurred. This places the preponderance of the ethical burden on an individual engineer to act or not to act. Forming engineers by modeling the actions of people such as Rachel Carson (who worked against toxins in the environment) or Roger Boisjoly (who warned about the O-rings in the Challenger Shuttle disaster) teaches ethics as an individual act rather than a collective one. An orientation towards whistle-blowing cases relies on the individual engineer’s moral responsibility to avoid engineering disasters instead of an institutional one. This belies the practical arenas in which most engineers work - arenas that are dominated by organizational decision making and chains of events that often are not the responsibility of or known to any one person.

Another approach to teaching engineering ethics attempts to solve the problems noted above by using hypothetical cases and problem solving tools to create what might be called ethics construction kits. Numerous books on engineering ethics present hypothetical cases that engineers are likely to face and introduce examples of the sort of reasoning they might employ to address these cases. These books tend to focus on providing students with tools and materials that, in theory, they can take away to solve problems they are likely to face 4,5,9. The problem solving tools most often are presented as various models to be followed or techniques to be applied. These models and techniques are taught to engineering students as standard procedures for dealing with difficult moral decisions.

For instance, the rational model involves at least five steps: (1) formulate the exact nature of the ethical problem or dilemma, (2) gather all the relevant facts, (3) identify competing moral viewpoints, (4) calculate the result, and (5) make a recommendation. The flow charting technique elaborates the rational model by using a flow chart so that the given ethical problem is visualized. Similarly, the line drawing method involves placing the “positive paradigm” at one end and “negative paradigm” at the other end, and drawing a line between them. Then, moral problems are placed in the appropriate place along the line. This method is based on the assumption that there are conflicting moral choices and yet a compromise is possible.

These prepackaged hypothetical ethical dilemmas and ethical problem solving methods have certain attractions. They allow instructors to cover a case in a single class period. Students may benefit from learning how to balance conflicting interests, gather accurate information relevant to the case, and make a hard choice. However, hypothetical reasoning tends to differ from real-
life reasoning. Hypothetical cases are generally presented in idealized forms, with little reference to contextual details of available resources, work practices, existing rules and regulations, workplace culture, and the history of ethical decision making. Without any reference to the context, these cases are seldom comprehensive. Consequently, the tools used and skills practiced in such hypothetical solutions are likely to function poorly in real situations.

IV. Linking Ethical Instruction with Engineering Practice

Considering that courses related to engineering ethics have increased dramatically in the 90s and new methods have been devised to study it, still, we think, it is not clear whether such courses ensure that engineering students will act effectively to protect public safety and welfare in their future careers. One reason is because scholars teaching engineering ethics seldom focus on how engineers actually understand and do engineering. We agree with Lynch and Kline that the failure to focus on ordinary ongoing engineering practice limits the likelihood that graduates will be able to identify features of their work setting that may call for ethical reflection. We believe that an understanding of moral theory, professional concepts for ethical behavior, codes of ethics, real and hypothetical cases, and ethical problem solving kits are important components of engineering ethics instruction. However, in order to mitigate potential threats to public safety, engineers should be able to reflect on the daily workplace and identify activities that are likely to lead to undesirable outcomes. In teaching engineering ethics, moral theory and codes of ethics are necessary, and case studies (real and hypothetical) are valuable. However, to bring them together effectively, instruction in engineering ethics must focus on the nature of engineering work itself.

As we hint above, the organizational reality of engineering practice is an important factor in this work. Unlike law and medicine, engineers are not self-employed. The private for-profit sector is by far the largest employer of engineers. In 1997, 77% of engineers with bachelor’s degrees, 75% of those with master’s degrees, and 54% of those with doctoral degrees were employed in a private, for-profit company. The basic purpose of industry is to make a profit, and it hires engineers to fulfill the objective of profit making. When engineers join industry, industrial goals and interests affect their professional conduct. Engineers are subject to control emanating from industry’s business objectives. The reality of practice is that engineers have to contribute to a firm’s profit to maintain their income. When students move from class to the industry, they face profit-making, hierarchical executive organization, and the premise of managerial decision making. These premises are different than engineering premises and sometimes complement and other times conflict with them. For example, companies may try to cover up or ignore serious problems, such as unsafe products, violations of environmental law, falsification of results, and discriminatory hiring and promotion. An excessive focus on an individual engineer’s ethical responsibilities currently prevalent in engineering ethics instruction is likely to lead to a conflict between engineers and the company, resulting in possible whistle-blowing by the engineers. It is, therefore, better to make engineering ethics courses oriented towards daily actions that do not appear to involve ethical concerns, but end up resulting in ethical dilemmas later on. The goal of engineering ethics instruction should be to make students sensitive to industrial elements in engineering practice. It should sensitize them to the way these elements form chains of decisions in which risk is often accreted and adduced little by little, rather than being present at
once dramatically in whole cloth. As such it might focus better on hierarchy and group decisions, rather than individual action.

We, however, do not believe that managerial culture is necessarily to be blamed for engineers’ capacity or lack thereof to make ethical decisions. Generally, scholars believe in the existence of inherent conflicts between managers representing corporate culture and engineers representing professional culture. Harris, Pritchard, and Rabins argue that a proper engineering decision is governed by technical matters that fall within engineering expertise and is within the ethical standards embodied in engineering codes; in contrast, a proper management decision involves factors relating to the well being of the organization such as cost, scheduling, and marketing. Managers are seen as overtaking engineering decisions. For instance, when engineers who had designed the booster recommended that the launch of the space shuttle Challenger be delayed under cold conditions, their management overruled them. A senior manager told the vice president for engineering to “Take off your engineering hat and put on your management hat.” This phrase has become famous in engineering ethics discussions. The infamy implicit in this statement is that management hats are “black” and engineering hats are “white” and that decisions taken by the former do not admit of the same ethical strictures, as do those of the latter. This position ignores at least two vital facts. First, the person making the decision was an engineer - otherwise there would be no need to “change hats”. Accordingly, the bad decision was as much an “engineer’s” decision as it was a “manager’s”. It is an example of an engineer making a bad and probably unethical decision. Second, the idea that somehow allowing factors like cost or schedules to trump factors like health and safety is a “proper” managerial decision misses a crucial point. Just like “proper” engineering decisions not only technical matters govern proper managerial decisions but also ethical standards embodied in professional codes of ethics. Like the engineering decision, the managerial decision in the Challenger case is an example of a manager making a bad and probably unethical decision. What the famous “two hat dictum” of the Challenger case really points out is the fact that in practice many engineers wear both hats and cannot, perhaps should not, take off either one. Instead they need to understand the ethics of both standpoints.

Moreover, by targeting management, engineers end up escaping their own responsibilities. Often, by the time engineers recognize the severity of a problem, the problematic design is already in place, has a life of its own, and it is hard to convince managers at such a stage that a problem suddenly exists. A better solution, therefore, is to resist risky calculation in the beginning. This is what we mean by the accretion and adducing of risk. Engineering instruction should focus on how engineers and managers manage risk on a day-to-day basis and how acceptance of low risk at one point can lead to high risk at a later stage. This will show engineers that to continue accepting low level risks in engineering design may eventually lead to high level problems. Vaughan argues that such incremental changes would make things safer at every stage. Without focusing on engineering practice, engineering ethicists end up promoting “crisis ethics” rather than “preventive ethics”. Passing the crisis on to “managers” to make the final decisions does not relieve the engineers from their responsibility in creating the crisis problematic.

Increasingly, engineers are handling technologies that are so interactively complex and tightly coupled that they are capable of causing serious unanticipated damage to people and the

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environment. Complexity of technological systems admits the possibility of hidden interactions that are not anticipated in the original design through branching patterns and feedback loops. Tightly coupled systems raise the possibility that interactions are mixed together with time-dependence and invariant order. Earlier technological systems were linear and loosely coupled, which allowed a system to recover from a setback. The most compelling technologies of the 21st century—genetic engineering, robotics, and nano technology—pose a new moral challenge that the technologies preceding them did not. Bill Joy, cofounder and Chief Scientist of Sun Microsystems and co-chair of the Presidential Information Technology Advisory Committee, has argued that new technologies can spawn whole new classes of accidents and abuses. Unlike 20th century technologies that employ large-scale linear activities, 21st century technologies like viruses and recent hacker attacks on popular Web Sites, are capable of self-replicating. Furthermore, they are within the reach of individuals or small groups to employ. Engineers making advances in such technologies, therefore, need to learn about the ethical issues implicit in what they are doing rather than just focusing on the technical issues. Joy admits that for the first time in his career and his life, he is concerned about ethical issues involving new technologies. Ethical issues in engineering designs of complex technologies rarely have a uniquely correct solution, which means students need to be educated on how value judgments enter in engineering decision making.

There is a great divide between the social and technical worlds. The triumph of positivist philosophy has made science "objective" and "value-neutral" and ethics "subjective" and "biased". Such positivist thinking is deeply entrenched in discourse of science and engineering. As students in engineering go through education and training, they learn that technology is objective, independent of social, cultural, and political factors. They are taught to confine themselves to technical issues and to remain neutral on social and ethical aspects of technology in the best tradition of science and intellectual impartiality. By positing technology as value free, ethical considerations have been removed from consideration in engineering practice. By focusing on routine engineering decisions and their long-term implications as part of chains of decisions, students can see that many such decisions are indeed value-laden rather than value free. Instruction in engineering ethics would then show that successful introduction of new technology depends on how well engineers are able to recognize and integrate both technical and social considerations in their engineering practice.

V. Conclusion

Finally, real-world contact with ethical issues should not be left to chance, but built into the engineering ethics course and the engineering community. In some respects, the goal of a good ethics course should be to dissolve the distinction between ethics "courses" and ethical "practices". One idea that we offer is to use electronic bulletin boards and chat rooms to both allow and indeed encourage students to openly discuss engineering ethics. Ideally, these sites would be active even when a course was not being offered and would be open to students once they had left an engineering program with their degree and had entered practice. This would give students somewhere to go both to seek advice on ethics once they have left academe, as well as to share experience about practice with both students and other practicing engineers. In a way, it would function as a sort of "ethical alumni society" as well as a course tool. Also, to establish a link between ethics in the classroom and ethics in the workplace, instructors should...
include speakers from industry whenever possible in their courses and try to enlist them as participants in the electronic forum mentioned above. In addition, instructors can ask students to find out what resources are available from various engineering companies for dealing with ethical concerns and, when possible, include them in the electronic network. The development of such a professional network would be invaluable to students, firms, and instructors. The latter could tap this network for experts, current cases, and materials. Of course one barrier to implementing this electronic connections idea is the real concern of firms with guarding intellectual property and the secrecy of business operations. These are legitimate preoccupations because these factors are genuine constituents of business profit. Nevertheless, the difficulties in working out such solutions in the academic environment can only help point up what is a central problematic for both teaching and practicing engineering ethics - the practice of engineering often dictates secrecy whereas the ethics of engineering requires transparency. It is the working out of the boundaries of these two domains that provides a challenge for the instructors, students, and practitioners of engineering ethics.

Bibliography
BRUCE PERLMAN
Bruce Perlman is an associate professor of public Administration at the University of New Mexico. He teaches research methods and public management among other courses. His research interests include ethics, philosophy of science, and development administration. He has worked as a consultant on a number of projects involving information technology in aviation, transportation, evaluation, and industry.

ROLI VARMA
Roli Varma is an assistant professor of Public Administration at the University of New Mexico. She also teaches science and technology studies courses for the school of engineering. Her research interests and publication include scientists working in industry, restructuring of corporate R&D, engineering ethics, and women and minorities in information technology. She is also interested in technology issues in India.