Strategies for Industry and University Cooperation in Engineering Ethics Education

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Abstract

The practice of engineering, in the context of the current society, is an extremely complex enterprise. This paper argues that a framework for ethical decision-making must consider corporate, social and global goals, as well as the objectives of the individual engineer. The ethical education of the engineer must be through collaboration among academic institutions, business interests, and professional engineering organizations. This paper recommends adoption of a single thread of ethics education, beginning early in life and continuing throughout the academic training and subsequent professional career of the engineer. Examples of current and proposed collaboration are given to illustrate the concept of single thread of ethics education.

I. Introduction

Engineering ethics education: the need for a broader and more inclusive perspective

The practice of engineering, like many other professional occupations, has become an increasingly complex and conflicted vocation. Decision-making complexities arise from both technical and non-technical considerations. As in any other undertaking, engineering projects are subject to the universal constraints of scope, budget and deadline. In addition, quality and safety must be considered to be paramount objectives. As any engineer can testify, these determinants often conflict; requiring prudent compromises and trade offs to be made among these goals from the outset of any engineering enterprise. At the worst, an engineer can begin a project virtually on the defensive, having been given unrealistic goals, inadequate budget, or too little time. This can create pressures to subordinate quality and safety considerations to attempt to meet these expectations. Society expects engineers to have the skills, perspectives, and support to make ethical decisions which balance the needs of society against the needs of the engineering enterprise.

Technical considerations also contribute to the complexity of engineering decision-making. Many students choose engineering because they believe it to be an "objective" or fact-based profession, in contrast to those occupations dealing more explicitly with value-based considerations, such as medicine or law. However, upon closer examination, there would seem to be much less precision in engineering than might be initially imagined. Consider, for example, the process of material selection for a product the engineer has been asked to design. While the physical characteristics of a material, and its behavior in certain situations, may be represented by a scalar quantity, or perhaps calculated using an exact formula, in fact these indicators quite likely have been derived from a variety of observations, and represent an average of responses. Further, the behavior of this material is often the result of properties which are in conflict, such as brittleness and hardness in tool steel, or reactions to compressive and torsional effects in concrete. Choice of the material must therefore be a trade off among such characteristics. After selection and design, the engineer must consider how the material will be assembled. Any raw material arrives at the production line with inherent flaws which the engineer must understand and take into account; will the assembly process aggravate these flaws, and leave the product with significant weaknesses? Finally, the engineer must consider the project life cycle, including maintenance procedures that can be expected to be applied from the introduction of the product to its last use, as well as final disposition of the product.

The last consideration for the engineer is the human element in his/her decision-making process. Who will be using the product? What is their skill level? Engineers often tend to assume greater technical literacy on the part of the consumer than in fact exists; a recent example of such optimism was the original Iridium satellite telephone system, which was a technical success but did not meet marketing expectations, partly since the system was extremely difficult to use by its intended consumers[1].

Far from being an objective decision-making process, the engineer is required to make trade offs among cost, benefit, risk and profit considerations in the face of incomplete information. In other words, the engineer is forced to make value-based decisions that are quite similar to any significant ethical question a member of current society is called upon to consider.

Engineering ethics education must be a collaborative process, considering individual, corporate, and societal concerns.

Although the various codes of engineering ethics can provide valuable guidance, there is no formula or "cookbook" which can be used to make such ambiguous and conflicted decisions. Rather, the engineer must consider the variety of objectives and constraints inherent in a framework including the individual, corporate and social goals on the broadest scale. Sound and high-quality ethical decisions cannot, in other words, be made by the engineer in a vacuum. The corporate ethical culture will perhaps be the most immediate manifestation of a more inclusive decision-making framework, and may in effect act as a proxy for broader social goals. In any case, only the corporation can provide the industry-specific information necessary to resolve some of the conflicts and ambiguities that are intrinsic to the decision-making process. Engineering societies, such as the National Society of Professional Engineers and state engineering licensing boards, can provide the general framework of ethical guidelines and requirements from society's stakeholder position. Ethical education of engineers must, therefore, be considered a collaboration among the immediate providers (academic institutions), the users (the business community), and society (professional and state engineering societies). While codes of ethics are of necessity addressed to the individual engineer, they must be embraced by the employers as well, for both parties have a major stake in the outcome.

Moral education must begin with the academic institution, and continue as collaboration between academic and business providers throughout the engineer's career.

It must be realized that engineers, even at the outset of their professional career, will have developed a fairly well-formed set of ethical principles. The goal of engineering education cannot, therefore, be to instill a variety of new precepts in the practitioner, for it is simply too late to have a significant effect on the moral framework of an individual. Rather, the job of the engineering educator should be viewed as a facilitator of professional and personal maturation, making the student aware of the stakeholders, nuances, complexities and ambiguities in the decision-making arena they are likely to encounter. While such education can be initially supplied by academic institutions, it is the corporate responsibility to continue this process, for the corporation will in effect provide much of the ethical framework for the engineer in subsequent years, and the source of much of this ethical and organizational context so necessary to making a sound decision. That is to say, this educational process must continue throughout an entire career, because the ethical framework will be changing during this period as well.

Ethics education collaboration between academic institutions and the business is required for intellectual property protection as well as the significant, and potentially disastrous, implications of unsound ethical engineering decisions.

Global competition, with the need to come to market quickly, provides relatively less tolerance for error in design than has been the case in the past. Companies must come to market quickly with a new design, but then they should expect this design to be copied or duplicated in major ways, requiring further rushed development of the product. As virtually any case study will demonstrate, serious design mistakes can and will be made in these circumstances, yet the consequences of mistakes can be magnified by the scale of potentially worldwide adoption of a technology. A major safeguard against such eventualities is the institution of a company-wide ethical culture which encourages unbiased peer-review of products early in the life cycle. A sound principle of engineering is that it is cheaper to fix mistakes early in the design process; by the same token, it is easier and less costly to address unsound ethical decisions if caught early as well.

Intellectual property protection is becoming an increasing concern among engineering employers. For a variety of reasons, a culture is developing which tolerates, if not promotes, unauthorized sharing of information across the Internet. It becomes easier and more attractive to copy corporate secrets as the engineering design process is conducted in the digital domain; one can transmit a CAD design by email with just a click of the button, rather than copy a paper-based design and walk out of the office. In addition, the intellectual property decisions by the court are certainly not definitive, and leave much room for ambiguity. Moral education is crucial to protecting the intellectual property of a company.

Certainly the consequences of major design failures can be disastrous for the company immediately involved. Indeed, recent experience has provided examples of companies that were effectively bankrupted and ruined by virtue of a single major engineering mistake. However, such mistakes can reverberate throughout the entire engineering marketplace as well. Legislators often react to the mistakes of a single firm by issuing restrictive legislation that affects all companies, imposing large costs on any providers of such products. A sound corporate ethical culture is an important safeguard against such mistakes, but this corporate culture must be reinforced by the culture of an entire industry as well. All companies that might be affected by such legislation must embrace an ethical culture to enable any individual corporation to effectively institutionalize these values.

Engineering firms do not need to be reminded of the potential legal liabilities of design mistakes. In recent years the court system has been willing to apply increasingly severe and comprehensive standards of responsibility for engineering mistakes, and there has been a dramatic increase in litigation. The corporation is typically regarded as responsible for the prevailing culture in which these decisions have been made. It is imperative that the firm adopt and actively enforce an ethical education program to safeguard against these eventualities.

In summary, it is extremely important for academic institutions to work together with businesses and engineering societies in a partnership to establish and maintain an ethical education program for engineers. All parties must share the responsibility for this enterprise. While the academic institution can provide a great deal of this education in the form of relevant theory, pertinent case studies, etc., the business must in turn supply the contextual information, such as corporate and social goals, that are required to completely address these ethical issues, while engineering societies can frame the ethical guidelines within a broader societal perspective.

II. Proposals / examples of collaboration

Single Thread of Ethics Education

Development of a continuous "single thread" of engineering ethics education, mentoring, and decision support is critical in order for engineers to develop and maintain an ethics perspective inclusive of corporate, social and individual stakeholders. The single thread concept starts with parents, religious leaders, civic leaders, and others during formative development of the student's core principal values. These individuals have a great impact on the ethical foundation that academia and employers have to build on in the future. These institutions must consider and account for differences in learned ethical principles between individuals. Ethics courses are becoming more important as well due to the blurring in society of the previously uniformly held distinctions between right and wrong. Perspectives and choices which were considered taboo ten years ago are now acceptable.

The role of the university in the Single Thread of Ethics Education

In many mechanical engineering curriculums a class in engineering ethics is a required part of the course of study. This training is essential for engineering professional development. The first engineering fundamentals examination for professional licensure includes questions on ethics based on lessons learned in class, while the Accreditation Board for Engineering and Technology (ABET) lists training in ethics as an expected and measurable engineering program outcome[2]. Concepts discussed in this academic context include professional responsibility and integrity issues, conflict of interest, consulting and research ethics issues, as well as associated engineering ethics issues dealing with the environmental and international perspectives.

To continue the thread of ethics learning and practice, professors need to interlace ethical decision-making skills into their various engineering classes. The Accreditation Board for Engineering and Technology criterion three, part f requires that ethics topics be interlaced throughout the various courses[2]. For example, a material science course could have students work problems and case scenarios about materials selection not only on stress properties but also on effects to the environment and resource sustainability. Another factor could involve the initial and long term cost of the decision involving the same environmental areas. This is especially true where product design priority has been for lower cost, which makes the product easy to throw away but too expensive to repair or recycle.

Most modern engineering courses now have or will use software based design/analysis packages in their curriculum. These programs are often extremely complex and require a good understanding of engineering principles to use effectively and accurately. If there is an error in the software, the inexperienced user may not be able to recognize this and could lead to dire ethical consequences to the user and society in general. Some instructors, including the authors, have found it effective to require the students to recalculate the computer generated results using hand calculations and approximate manual equations to validate the software results. Software control courses should also discuss the "what if" scenarios of all possible combinations of operations and the ramifications of particular control methodologies. For example, suppose a manufacturer uses a software program to control a fabrication process, but subsequently discovers that the product has ceased to meet specifications. The fault could lie in the software as well as the hardware, and once again one must pay attention to software issues to avoid potential adverse ethical consequences.

Design courses are a particular area where ethical decision-making principles should be incorporated. Design courses typically include discussion of factor of safety and failure modes, but should also include a contingency factor of how someone might operate or use the design in various scenarios. In addition, current design trends optimize the design to lower factors of safety due to better understanding of the failure modes as well as use of materials with consistent properties. The design curriculum should incorporate student assessments of situations where the design is based on the lower limits of the specification and possible variation in material properties may exist.

Professors must also demonstrate and enforce ethical decision-making in the classroom as a part of ethics training. In his study of cheating in the classroom, Koch[3] cited a 1999 U.S. News & World Report poll which indicated that 64% of the public polled feel that college students cheat frequently. If the students cheat on their examinations, there is no guarantee that they have adequately learned the material. Koch quotes Dr. Donald McCabe, founder of the Center for Academic Integrity based in Durham, North Carolina to emphasize the seriousness of this deficiency: "Do you want to go to a doctor who cheated his way through anatomy class, or drive over a bridge built by an engineer who cheated?" [3]. Defining academic expectations and consequences of cheating (failing course, transcript notation, and expulsion) is one method to discourage the practice.

Finally, expected ethical practices in engineering should be clearly defined as well as academic ethical practices. Since the ethical decision-making skills of the student can be formed through direct study and through the normal course of academic training, ethical academic practice is essential to ensure ethical engineering practice. This linkage must be made with students in the initial ethics class and throughout the academic curriculum. Engineering professors can serve as role models as well as mentors during the student's academic career to facilitate this training.

The role of the company in the Single Thread of Ethics Education

Industry can provide a continuing role in the ethics education of engineering students as well. Cooperative projects involving industry, such as senior design projects, give the students and the company advisor a chance to work side by side on a design or research and development project. This fosters understanding of common problems and helps extend the single thread of ethics education from the academia to the industry perspective.

By the same token, speakers hosted jointly by business and university can provide a common forum for discussion of ethical issues. In particular, there are numerous speakers available to discuss engineering ethical education issues. These speakers are especially effective because they are practicing engineers who have experienced and dealt with these issues first hand.
In-house and joint presentations give the two groups a way to share common concerns and successes in an informal atmosphere. These joint presentations are commonly done for various engineering-related topics such as design methodology, safety, ergonomics, and other areas, but should include explicit discussion of ethical issues as well.

Another option which would include the company in ethics education and practice is establishment of an ethics review board. An ethics review board should report to a company's or university's board of directors, not the president or other officer, in order to maximize their independence. Many companies and universities assign the ethics duties to the Human Resources (HR) department. While this is important, many times the HR staff does not have the technical knowledge to fully understand the ethical situation. The decision is usually made by just one HR person, which makes it extremely difficult for them to integrate the various business, technical, and legal issues into the ethics decision-making process. By the very nature of the situation, the ethics-related issue cannot be discussed outside of the company, and usually must be resolved internally. This is one reason why the ethics board concept becomes important.

A possible makeup of a board would have representatives from human resources and the legal department, engineering (experienced with professional licensure), management (20-30 years middle management experience), academia (tenured engineering professor) and the public (member of engineering society such as a retired engineer). This makeup allows all stakeholders to be represented. The human resources and legal departments will bring to the table the various aspects of the employment law, i.e. contracts, agency, tort, and others. The professional engineer, through accumulated training and experience, will understand role and responsibility that a person will have to protect the public health and safety.

Finally, ethics mentoring is a method by which industry can foster and pass on ethical decision-making skills. Ethics mentoring is an informal review process which involves mentors as role models who have a vested interest in promoting ethical behavior. They would give the involved engineer a chance to talk the problem out with a concerned and qualified person who would offer suggested options to resolving the dilemma. Presently the method occurs ad hoc, but having a list of mentor volunteers and/or pairing engineers with mentors would provide an avenue for soliciting advice.

The role of professional societies in the Single Thread of Ethics Education

Professional engineering societies such as the American Society of Mechanical Engineers (ASME), the National Society of Professional Engineers (NSPE), and the American Society of Civil Engineers (ASCE) each have a professional code of ethical conduct for their members which provides another avenue for ethics education and monitoring. In addition, these societies also provide funding and volunteers to National Institute of Engineering Ethics to promote engineering ethics education. Finally, these societies also provide a means to ask engineering ethics questions in a neutral way to get possible solutions independent of the industry. Since unethical conduct can result in expulsion, loss of membership and public censure, business and academic interests alike should take advantage of the resources mentioned above.

The role of state boards in the Single Thread of Ethics Education

The state boards have jurisdiction over engineering practice in their state. The Kansas State Board of Technical Professions Rules and Regulations (KSBTP) has a provision (Article 66-6-4) dealing with unethical practice and professional conduct[4]. Ethical cases that reach the state board for investigation are regarded as very serious; therefore it is important that the ethical issues be dealt with early on rather later by the professional engineer. The state board can revoke one‘s engineer license, thus eliminating one’s livelihood for ethical misconduct. This proceeding is public knowledge and is shared with other state boards. Many times other state boards will also then act to revoke the engineer’s license in their state.

III. Conclusions

Engineering practice is becoming increasingly complex in its application, requirements, and expectations. New engineers need to have a "single thread" of ethics education that bridges the gap between academic education and professional practice. Inclusion of ethics training throughout the engineering curriculum, as well as continued training in industry, access to mentors, and availability of an ethics board are several methods of maintaining continuity in ethics education and practice. Professional engineering societies and state regulatory boards consider the public interest, and have resources and requirements which can help define expected conduct to guide academic and industry practice.

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