ETHICS EDUCATION FOR ENGINEERING STUDENTS

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ABSTRACT. Ethics in engineering practice is about professional responsibilities of engineers. Professional ethics have been recognized as an important foundation in the practice of engineering for several decades in many industrialized countries. Codes of ethics have been invoked as a basis for professional engineering licensure. Violations of such ethical codes have led to many well-known tragic engineering failures that endangered human life and jeopardized public welfare. As a response to this concern, a new discipline, engineering ethics, is emerging. Recently, engineering ethics has attracted the attention of several colleges of engineering around the world. In this regard, ethics started merging into engineering curricula for the last two decades. Implementations varied from introducing some ethics case studies into existing courses, to introducing standalone ethics courses. This paper addresses this important educational issue, highlights the need to introduce ethics at an early stage to engineering students, and sheds the light on the existing practices in some engineering schools.

1. INTRODUCTION

Engineering products and applications are essential to everyday activities in our life. These include housing, transportations, communications, and other industrial processes. In order to safeguard life, health and property, and to promote public welfare, the practice of engineering is treated as a learned profession, and its practitioners shall be held accountable by high professional standards in keeping with the ethics and practices of other learned professions. Accordingly, the leading industrial countries have ruled that no person shall practice engineering unless registered as a professional engineer. In the United States, the regulation of the practice of the engineering profession dates back to the beginning of the 19th century. The first board of licensure for professional engineers was established in 1907 in the State of Wyoming [1, 2]. Today, the engineering profession is regulated in all the leading industrial countries by a set of established regulations. In order to establish and maintain a high standard of integrity, skills, and practice in the profession of engineering, Rules of Professional Conduct (Code of Ethics) are enacted. All persons licensed or certified under such provisions, are charged with having knowledge of the existence of the Code of Ethics, and are deemed to be familiar with their several provisions and to understand them. Such knowledge encompasses the understanding that the practice of engineering is a privilege, as opposed to a right, and the licensed engineer should be forthright and candid in his statements or written response to the authorities on matters pertaining to professional conduct.

The importance of understanding the principles of engineering ethics and professional conduct was manifested by the appearance of several books on the subject. Some books [3, 4] were published in the early 1960s to emphasize the importance of professional ethics and to provide a clear understanding of the terms and concepts of engineering ethics. Several other books followed [5-12], with the most recent ones [10-12] written as textbooks for some proposed ethics courses.

2. BASIC MORAL RULES IN ENGINEERING PRACTICE

The basic moral rules specify the acts or course of actions required, forbidden or permitted. These concepts need to be made clear, understood and acquired by engineering students, thus becoming an integral part of their developing professional character before they embark on their career as responsible engineers. Professional responsibility is known as the most common type of moral responsibility that arises from the special knowledge a person possesses. Mastery of a special body of knowledge that bears directly on the well-being of others, distinguishes professions from other occupations, [11]. Although some moral demands on professional engineers are adequately expressed in rules of conduct that specify what acts are permissible, obligatory, or prohibited, there is more to acting responsibly than following the rules. A good engineer not only shuns briefly, checks plans before signing off on them, and the like, but also must exercise judgment and discretion to provide a design or product that is safe and of high quality. Professionals in particular, must decide what to do to best achieve good outcomes in matters entrusted to their care.

The achievement of a desired outcome involves some exercise of discretion or judgment. Such training is certainly more beneficial and less harmful, when exercised in a learning environment. Building the sense of professional responsibility is doubtless an educational issue.

3. INTERST IN ENGINEERING ETHICS

Recently, the engineering ethics has attracted increasing interest, at least in part, as a result of the attention that the media has given to cases such as the Challenger disaster, the Kansas City Hyatt-Regency Hotel walkways collapse, the Exxon oil spill, Chernobyl nuclear leak, and Union Carbide accident in Bhopal. As a response to this concern, a new discipline, engineering ethics, is emerging. The need to introduce engineering ethics at an early stage to engineering students was deemed essential.

It is important to note that engineering ethics has attracted the attention of several colleges of engineering, as manifested by the effort made to introduce ethics case studies into required undergraduate engineering courses. Evidence of this interest in professional ethics is demonstrated by the following examples:

- The National Institute for Engineering Ethics (NIEE) was established in 1988 by the National Society for Professional Engineers. Later, the ***Murdough Center for Engineering Professionalism*** was established at ***Texas Tech*** to operate the NIEE programs for promoting engineering ethics. The Murdough Center and its affiliated programs are designed to prepare students to be ethical leaders and decision makers, and able to think critically with sound reasoning ability. The center offers a set of engineering professional ethics courses by correspondence.
- At ***Texas A&M University***, the National Science Foundation funded a project to develop material for introducing ethical issues into the required undergraduate engineering courses. The project was concluded in 1992 by developing a new course in engineering ethics.
- In the fall of 1995, the ***Online Ethics Center for Engineering and Science*** was established at ***Case Western Reserve University*** under a grant from the National Science Foundation. The mission of the Ethics Center is to provide engineers, scientists and science and engineering students with resources useful for understanding and addressing ethically significant problems that arise in their work life. The Center is also intended to serve teachers of engineering and science students who want to include discussion of ethical problems closely related to

technical subjects as a part of science and engineering courses, or in free-standing subjects in professional ethics or in research ethics for such students.

- In 1995, the school of engineering at ***Delft University of Technology*** started offering a required senior undergraduate course in engineering ethics.
- A European Work Group, ***Ethics in Engineering Education*** (EiEE), was formed in 1998 to establish and activate a network of educators and practicing engineers who want to develop ethics education, address the need for ethics in the engineering curricula, and exchange the experiences and teaching material developed in engineering schools.

Although, the aforementioned examples are not intended to represent a comprehensive survey, they clearly display worldwide awareness of the significance of learning and understanding engineering ethics, as a part of engineering education.

4. ETHICS REQUIREMENTS BY ABET

ABET 2000 Outcomes includes "an understanding of professional and ethical responsibility." Most engineering educators are unsure how to include this element in their curriculum, and even if they do have some idea, are almost uncertain about its assessment; whether or not this outcome has been achieved. It should be noted that this criterion requires only an "understanding of", as contrasted with most of the criteria that require "ability to". While this difference makes the criterion relatively easier to accomplish, it should still be the goal of engineering programs to seek to go beyond graduates who merely hear about engineering ethics to graduates who can function ethically.

The challenge that ABET has provided engineering schools in relation to the teaching of ethics can be simply stated as, to teach students arguments and theories about what actions are right (or wrong), and which states of affairs are good (or bad) related to the professional practice of engineering. Additionally, students need to be provided with structured opportunities to make ethical decisions related to engineering practice. A potential list of what students need to do in order to satisfy this outcome is given in [14].

Nevertheless, three key issues pertinent to the content, teaching methods, and outcome assessment methods, remain unresolved. Yet, there are no unified guidelines as to how the ethics content, teaching and assessment methods would be selected or implemented. The members of the engineering ethics community should work at providing a feasible framework for the aforementioned issues. Ultimately, this will require a greater effort on the part of engineering practitioners, engineering educators and engineering students.

5. TEACHING ENGINEERING ETHICS

The importance of teaching engineering ethics at the undergraduate level is to improve the students' awareness of the challenging task of tackling ethical problems. Students need to reorganize that there is rarely a uniquely correct solution or response to substantive ethical problems. Ethical or moral problems are often, represented as conflicts between two opposing sides or opposing principles, but they are often better understood as problems in which there are multiple ethical constraints which may or may not turn out to be simultaneously feasible. Teaching engineering ethics can achieve at least the following four desirable outcomes, [13]:

- Teaching ethics can increase student sensitivity simply by making students aware that they, as engineers, will have to resolve certain ethical problems. Generally, pointing out an ethical problem will mean pointing out the consequences of a seemingly inconsequential act.

- ❖ Teaching ethics would increase student knowledge of relevant standards, e.g. formal codes of ethics as those adopted by the National Society of Professional Engineers (NSPE) or the Accreditation Board of Engineering and Technology (ABET). Knowledge of standards includes understanding their rationale (especially the consequences of departing from them), and interpretation taking into account not only its rationale but other moral and practical constraints, including the interpretation others are likely to envision.
- ❖ Teaching engineering ethics improves ethical judgment, which tends to improve with use, like any other judgment.
- ❖ Teaching engineering ethics improves ethical will-power (that is, a greater ability to act ethically when one wants to).

Models attempted in teaching engineering ethics:

The following four models are devised to introduce ethics education into the engineering curriculum, [14]:

- A required course in engineering ethics for all engineering students. This model, though successful at Texas A&M University, the school of engineering at Delft University of Technology and a few smaller institutions is unlikely to gain widespread favor. This is due to the high cost of such endeavors in terms of faculty time and an already tightly structured engineering curriculum. In addition, unless supplemented by further instruction in engineering ethics in mainstream engineering courses, this method can leave students with the impression that ethics is a sidebar rather than integral part of their engineering studies
- An across-the-curriculum model for engineering ethics. This approach seeks to address the limitations of the required course model by spreading engineering ethics instruction throughout the engineering curriculum, e.g., in introduction to engineering courses, sophomore engineering science courses, junior discipline-based courses, and senior design experiences. The key to the success of this model is overcoming engineering faculty resistance to the importance of ethics instruction, and demonstrating to them, through faculty development initiatives, how ethics material can be incorporated in their classes. The engineering curriculum initiative at the University of Michigan is one such effort.
- Integration of engineering ethics instruction with material that focuses on the social context of engineering. Such an integrated curriculum model for computer science was developed in a project funded by the National Science Foundation. The authors of the study advocate an across-the-curriculum approach supplemented by a required course. A successful example of this model in an engineering context is the Program on Technology, Culture and Communication (TCC) at the University of Virginia's School of Engineering and Applied Science. All engineering students take a four-course core from this program including 0.5 to 1.5 semesters worth of engineering ethics content, most of which is included in a two course senior sequence, "Western Technology and Culture," and "The Engineer in Society". Integration with the overall engineering curriculum is achieved through a required senior thesis on the social impacts of a technical project that is advised by a member of the TCC faculty.
- An integrated humanities and social sciences program that seeks to address all of the non-technical outcomes specified in ABET 2000 Criterion 3. Taking the Engineering Ethics/STS model one step further, a group of universities led by Illinois Institute of Technology is conducting a three-year project focused on development of traditional

courses and across-the-curriculum initiatives that will comprise an integrated response to the humanities-oriented outcomes of Criteria 2000, in such areas as engineering ethics, business-humanities interaction, social and environmental context, and history of the engineering profession.

Due to the diversity in engineering programs, it is likely that all of these models, and perhaps others, will be brought to bear in implementing a response to Criteria 2000.

6. CONCLUSIONS & RECOMMENDATIONS

6.1. Conclusions

Engineering educators concluded that ethics should be an integral part of the engineering education, where engineering students (future engineers) need to be taught how to make a value judgment, understand what is ethically significant, and assess the impact of their actions.

Addressing the engineering ethics requirement of Criteria 2000 through new course offerings would be a major challenge for engineering schools. Based on a survey of undergraduate catalogues of ABET accredited institutions, [13] determined that in nearly 70% of the institutions there is no ethics-related course requirement for all students. When the results are normalized to account for number of graduates per institution, nearly 80% of engineering graduates attend schools that have no ethics-related course requirement for all students. While 16% of institutions and 7% of graduates do have one or more courses with ethics-related content, these courses are usually not courses in engineering ethics, but rather courses in philosophy, religion, etc.

A primary responsibility of faculty is development of a course of study which prepares engineering students for the practice of engineering in the world that those students will experience during their professional careers. This responsibility inures to the benefit not only of students, but also of the society that those students will serve. Development of curriculum should not be reduced to an exercise in fulfilling the requirements set forth by the Accreditation Board for Engineering and Technology (ABET). Fortunately, the responsibility of faculty in developing curriculum for engineering students does not conflict with requirements for ABETS accreditation. In fact, the ABET requirements support the development of strong engineering curriculum.

Generally, however, approaches that require coordination and cooperation between faculty members within a department or between faculty members from different departments will require more effort to successfully implement than an individual course. Any successful strategy needs to consider minimization of the cost in terms of faculty time and curriculum hours, instruction in a number of courses so as to prevent students from gaining the impression that ethics is a side issue that is not really important, and mentoring (role-modeling) by faculty.

6.2. Recommendations

A practical way to introduce ethics education into the engineering curricula in the Arab universities is by integrating ethics topics into the engineering curriculum through an across-the-curriculum approach. This approach, which is adopted recently by many colleges and universities [15], insures that problems, projects, and other educational experiences which teach engineering ethics are included in a variety of courses, both technical and non-technical, throughout the curriculum.

The integrated approach may be viewed as twofold. Firstly, topics on general professional ethics can be easily added and taught within the topics of general studies courses (i.e. humanities, social and religion courses). Secondly, a set of engineering failure case studies related to professional ethics can be introduced into a number of junior and senior engineering courses. 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.

The case study can be either tackled as a demonstration example of design failure, or as a topic for a term project. Candidate courses for such implementation include senior design project, some selected junior engineering courses, most of the senior engineering courses, and all engineering elective courses.

While it is not as easy to verify the process of instruction under this integrated approach 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, [15]. 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.

It is important to note that the key to the success of this approach is by overcoming engineering faculty resistance to the importance of ethics instruction, and demonstrating to them, through faculty development initiatives (e.g. through the Deanship of Academic Development at KFUPM), how ethics material can be incorporated in their classes.

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