INTEGRATING ETHICS INTO ENGINEERING EDUCATION

L. Mohd. Sidek[a,b] , F. Tarlochan[a,b] , K. Nasharuddin[a] and M. Z. Yusof[a]
[a]College of Engineering, Universiti Tenaga Nasional (UNITEN), 43009 Kajang, Selangor, Malaysia
[b]Engineering Education Technical Division, Institute of Engineers Malaysia (IEM),
Email: lariyah@uniten.edu.my

ABSTRACT

Ethics and professional conduct are vital to engineering undergraduate curricula. Many programs struggle to ensure that students are given exposure to and appreciation of ethical and professional conduct issues. 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 Malaysia. 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. Generally engineering education produces technically competent graduates by demanding extensive and rigorous course and laboratory work. However, there is a demand to equip the graduate with soft skills to become a holistic, dynamic and multi-skill engineer as future leaders in the industry. In order to ensure the graduates engage in a life-long pattern of ethical and professional behavior, College of Engineering (COE) has taken a pro-active measures by providing them with a correspondingly deep education in (i) the underlying theory and practice of ethics and professionalism (as taught from an engineering perspective), (ii) historical or case study context along with the impact of technology on society and (iii) PBL approach for professional development in engineering education strategy that enable students to evaluate a given scenario, identify, search & gather relevant information, work in teams, reason and justify to form opinions, apply various known tools, convince others and reflect regularly on whatever they do. Hence, the engineering program will definitely meet EAC criteria related to ethics and professionalism. This paper describes an experience to develop engineering ethics in engineering student. This experience was part of the upgrading of the engineering undergraduate curriculum, at College of Engineering, with a systematic program design to develop the ethics in students while studying at UNITEN. In this paper we also identify resource materials, background information, a syllabus, and outline for teaching a course on professional and ethical aspects of engineering education. Results indicate that most students after taking Engineers in Society (EIS) subject will be more tactful in making decision when face with moral dilemma due to appropriate preparation to face these issues through EIS subject and highly appreciated having a course at university that would assist them to handle moral and engineering dilemma in future.

INTRODUCTION

The aims of engineering education inevitably include the learning and understanding of fundamental engineering concepts and the development of appropriate solutions to the problems related to the topics in the curriculum. The problems in the course should cover the process of observing engineering related phenomena, understanding of concepts, statement and the search of different alternatives as solutions to the problem at hand. However, engineering education is more than that.

The elaboration of a standard of practice or code of ethics was an intrinsic part of the establishment of engineering as a profession (EAC, 2006) and as such remains one of its essential components. The EAC Engineering Criteria 2006 acknowledges the importance of including ethics in the training of an engineer. Item "g" of EAC Program Outcomes, stipulates that engineering graduates must demonstrate "an understanding of professional and ethical responsibility and commitment to these." Analogously, item "i" states that the graduates must demonstrate "understanding of the social, cultural, global and environmental responsibilities of a professional engineer, and the need for sustainable development". Our experience has shown that an effective and efficient manner to meet this EAC 2006 ethics challenge is a program of ethics across the curriculum (EAC) integrated with a course in EIS that covers engineering ethics.

In the famous article about engineering education written by Dym (2003) had summarized his observations to engineering education into the following 5 points: (1) Engineering curriculum has been designed to be highly structured, locked in too long, serial course sequences; (2) This curricular organization has been institutionalized

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within an engineering science model of engineering, and is delivered within academic cultures that clearly conform to the scientific research enterprise: (3) We seem to convey to all students the idea that mathematics is the language of engineering: (4) We have done a much better job teaching analysis than we have done teaching design: (5) We conduct the engineering education enterprise in an environment in which each student's performance is largely assessed in individual terms, often in styles that encourage each student to see herself as being in competition with her peers.

Many of calls for engineering education reform from industry (based on comments by IAP & employers) have focused primarily on issues related to the attitudes and soft skills required to prepare engineers generally for the profession, such as communication skills, teamwork, lifelong learning and ethics. These efforts have also been supported by initiatives to change the learning environment in which engineering is taught and to rely less on traditional lecture formats and increasingly on the creative aspects of engineering using active learning (Barakat, 2005) and problem based learning to more effectively engage students (EAC, 2006). The teaching of engineering ethics is on the increase at universities in the country. The motivation for this increase (WHY?) has several driving forces, including: a new Engineering Accreditation Council (EAC) accreditation criteria; new questions on Professional Engineering (PE) licensing examinations; new industrial marketplace needs; and a growing awareness in the engineering profession of a need for ethical sensitivity to the consequences of our actions as engineers.

In this paper we describe the tools and strategies used at the COE, UNITEN to foster EAC requirements with the aim to achieve the Program Educational Objective No. 2 "Uphold professional attitudes and ethics necessary in fulfilling his/her responsibilities towards the Almighty, clients and the society" and Program Outcome No. 6 "Aware of professional and ethical responsibilities" and to instantiate its continuous improvement. The initiative to enhance the ethics and professionalism in EIS subjects is based on the comments by the Industrial Advisory panels (IAP), External examiners, Industry and other stakeholders. This paper also explores the PBL approach for professional development in engineering education strategy that enable students to evaluate a given scenario, identify, search & gather relevant information, work in teams, reason & justify to form opinions, apply various known tools, convince others and reflect regularly on whatever they do. Hence, the PEO No 2 is achieved and UNITEN will continue to generate professionals with strong ethical and professional background.

ENGINEERING AS A PROFESSION

To understand why the engineering education needs to be changed, we first have to understand engineering as a profession. The key for engineering education is to prepare students as an engineering professional instead of providing them with an entry-level certification for the profession Dym, C. L. (2003). The students should know engineering practice does not resemble engineering in university only, with its never-ending lab reports, mathematical manipulations and books but it goes beyond that.

Profession is defined as a calling requiring specialized knowledge and often long and intensive preparation including instruction in skills and methods as well as in the scientific, historical, or scholarly principles underlying such skills and methods, maintaining by force of organization concerted opinion high standards of achievement and conduct, and committing its members to continued study and to a kind of work which has for its prime purpose the rendering of a public service (IEM, 2005). Engineering is a profession by this definition. Profession occupations possess the following characteristics Luegenbiehl H. S. (2003). First, entrance into a profession typically requires an extensive period of training, and this training is of an intellectual character. That is, a member of a professional community must master certain theoretical and technical knowledge that the general public cannot easily acquire. Second, professionals' knowledge and skills are vital to the well being of the larger society. Third, professions usually have a monopoly or near monopoly on the provision of professional services. Fourth, professionals often have an unusual degree of autonomy in the workplace. Last, professionals claim to be regulated by ethical standards, which are usually embodied in a code of ethics. Because of the nature of engineering profession, engineering ethics is more preventive ethics. In today's world, economization converts professional-client relationships into ones based on financial incentives, allowing market forces to determine the quality of the professional-client interactions. This is one way where the moral duty of professionals to the society can get overshadowed by financial considerations.

In the eyes of the public, employers and students, the university provides a kind of certification that entitles graduates to certain privileges. The faculties in the university that conduct programmes leading to so-called professional degrees tend to consider the education they provide as a form of training. Professional organizations, which license professionals and issue practicing certificates, formally recognize university degrees as if university degrees certify certain abilities. On the other hand, some look at university education as the development of intellectual maturity. One can view both provision of training and development of intellectual abilities, as ways of certification for admitting individuals to a certain set of communities. In this sense, university teachers are agents from a community who nurture and help others in getting admitted to their community, be it a community of intellectuals or a community of practitioners or both Harris, C.E. et.al (2005). That means educating someone to become a professional is a special responsibility. For engineering education, holism is a necessity. We need an education strategy that will make students regularly evaluate a given scenario, identify, search and gather relevant information, work in teams, reason and justify to form opinions, apply various known tools, convinced others and reflect regularly on whatever they do. The most important the students will have professional preparation and courage to make any decision making when face the real moral dilemma in working life.

ENGINEERING ETHICS

Engineering ethics is a wide topic that brings most of the non-technical issues including the professional, human, and societal ones, into the engineering curriculum, aiming at making the graduating engineers technically competent, ethically sensitive, and socially aware. The context of engineering practice has become more common than before, which brings with it a mixture of technical challenges from the different people, societies, and cultures. Consequently, the mobility and competitiveness of engineers becomes not only related to the recognition of their qualifications but also to their ability to function in different technical, social, and cultural setting. The EAC accreditation criteria (2006) for engineering programs outcomes and assessment emphasize this idea of ability to function on multi-disciplinary teams and the understanding of professional and ethical responsibility as well as the broad education necessary to understand the impact of engineering solutions in a global and societal context.

EIS COURSE DEVELOPMENTS

As part of the efforts to upgrade the graduate curriculum at COE, UNITEN, a set of courses was introduced and designated as a degree requirement to fulfill the gaps usually left in an engineer's undergraduate preparation and bring the graduate students at COE up to the same level of preparation. These courses aim also at providing a continuing education opportunity for practicing engineers treating most recent skills and issues faced by the engineers. The course containing the module under discussion is from this set and was offered in subject Engineers in Society COEB422/COEB423. The course takes a balanced approach to most of the qualitative and contemporary issues facing engineers in their practice that are not usually covered in depth in undergraduate curricula. The course includes modules covering the following issues:

<u>Module 1</u>

1 Introduction to Engineers and Society – Role of Engineers
2 Engineering and history and Social Dimension of Engineering
3 Engineering education, engineering societies (IEM) and engineering boards (BEM)
4 Engineering professionalism and ethics
5 BEM Code of Professional Conducts and IEM Code of Ethics
6 Ethical problems identification, analysis and solution (Case Study)

<u>Module 2</u>

1. Communication
2. Development and it's impact on the environment including the Environmental Ethics, Green design and Sustainability
3. Standards and Quality

<u>Module 3</u>

1. Teamwork & Leadership

<u>Module 4</u>

1. Project Management
2. Occupational Safety and Health
3. Intellectual property

At the end of the course the students are expected to understand basic concepts and methods in ethics, typical professional engineering society code of conduct, history of engineering and technology, organizational loyalty versus professional rights, engineers and the environment, risk and the engineering decision-making process, whistleblowing, social responsibility versus legal liability and other topics related to engineering practice.

Module 1 includes a classroom presentation combined with an open discussion followed by a team active learning exercise. More discussion and comments follow the team exercise outcome. The result is a list of open issues and relevant ideas which are to be pursued through a follow up assignment and the course project. The course project included a paper on a course topic that can be chosen by the student with a limitation on the number of projects per category to guarantee diversity. The students have to form a group of maximum 5 students with different background such as race, gender and etc and must be approved by the lecturer in-charge of the group project. The idea is to expose students to work with people from different races, genders and somebody that they never work before. The course outcome of the course is to enhance interpersonal, communication, teamwork, leadership, social and management skills which will be achieved through the group project at the end of the course. In order to make the course more interesting, a different teaching and learning delivery methods were used in the class such as external speaker from Anti-Corruption Agency (ACA) was invited to talk on unethical practices by engineers and IEM to talk on professionalism.

CODE OF ETHICS MODULE IN EIS

Generally, BEM's Code of Professional Conduct rules govern the conduct of an engineer in relation to his employment or practice as a Consulting Engineer and abide to the law. It should be noted that the general IEM Code of Ethics are sets of rules meant to guide the professional's conduct. However, BEM's **Code of Professional Conduct** extends beyond moral obligations as it has the force of law and breach of any of the rules embodied in the code may subject the offender to penalties provided for under the Engineer's Act including the ultimate penalty of deregistration.

The details of the Code of Professional Conduct were discussed in class and given example to violation of Code of professional Conduct based on case study of engineering failures in Malaysia. The students will be introduced with the Code of Professional Conduct of BEM's as follows:

1 A Registered Engineer shall at all times hold paramount the safety, health and welfare of the public.
2 A Registered Engineer shall undertake assignments only if he is qualified by education and experience in the specific technical fields in which he is involved.
3 A Registered Engineer shall issue public statements only in an objective and truthful manner
4 A Registered Engineer shall act for each employer or clients as faithful agent or trustee
5 A Registered Engineer shall conduct himself honourably, responsibly, ethically and lawfully so as to enhance the honour, reputation and usefulness of the profession.

In addition, the students will be taught with the Do's and Dont's as guidelines for the young engineers to start engineering practice right after graduation. The Do's and Dont's were extracted from original BEM Code of Professional Conducts due to many complaints by public on the failure of engineering projects. Under the Registration of Engineers Act 1967 (Act 138) and subsequent amendments, the most recent being year 2002, it is a requirement of the Law that any person providing engineering services be a qualified person and registered with BEM. This requirement extends to foreigners who are required to seek registration as Temporary Engineer. The details of the Do's and Dont's for young engineer can be referred to Table 1.

Table 1: Guideline (Do's and Dont's) for Young Engineers Related to BEM's Code of Professional Conducts

Registration **Do's for Young Engineers**	 **Dont's for Young Engineers**
1.1 An engineering graduate with accredited engineering degree must register with the BEM to take up employment as an engineer	1.1 An engineer should not be the Submitting Person for designs beyond his/her area of competency 1.2 An engineer should not endorse his PE Stamp and sign on reports or plans not prepared by him. 1.3 An engineer should not enter into partnership with any party not permitted under the Engineers Act. 1.4 An Engineering Consultancy practice should not provide professional services in any branch of engineering where none of its directors are registered to practice in that branch of engineering 1.5 An engineer must not practice in the branch of engineering he is not registered in.
Consultancy **Do's for Young Engineers**	 **Dont's for Young Engineers**
2.1 An engineer should be transparent and receptive to peer review or checking of his work if requested/required by the client/authorities 2.2 A checker engineer must be open to the views and design concept of the original designer and in areas of disagreement the checker must give justification for his disagreement. 2.3 A checker engineer should take full resposibility for the checking of the work himself. 2.4 An engineer should undertake CPD to enhance his knowledge and capability 2.5 An employer engineer should ensure that his employee engineers are BONA FIDE engineers registered with BEM. 2.6 An engineer should report unethical practice to BEM 2.7 An engineer who is Submitting Person must ensure the accuracy of and be responsible for all works delegated to others by him. 2.8 An engineer should make optimum use of manpower, materials and money. 2.9 An engineer should be aware of Government requirement to use local materials, whereever possible.	2.1 A checker should not accept checking of work not within his area of competency as well as work that he is not familiar with. 2.2 An engineering consultant should not carry out projects for fees below the minimum outlined in the scale of fees. 2.3 An engineer should not endorse any work not performed and/or supervised by him. 2.4 An engineer should not supplant another engineer. 2.5 An engineer should not compromise on public safety. 2.6 An engineer should not offer his opinion on engineering matters unless he ahs full facts to support the opinion. 2.7 An engineer should not base his design on unsubstantiated data, for e.g. designing foundation without soil investigation. 2.8 An engineer should not have any conflict of interest whatsoever in connection with the work he is undertaking unless prior approval from BEM and client are obtained. 2.9 An engineer should not accept work outside his regular work without the expressed permission of his employer.
Supervision **Do's for Young Engineers**	 **Dont's for Young Engineers**
3.1 An engineer who is the Submitting Person should be responsible for the project regardless of whether it	3.1 An engineer must not over or under certify progress of works.

is self-supervised and/or delegated supervision. 3.2 An engineer must be meticulously proper and correct in certification of works. 3.3 An engineer must be familiar with and knowledgeable in the work he is to supervise. 3.4 An employer engineer shall ensure that his staff undergoes regular and proper skills-training. 3.5 An engineer supervising a project shall keep proper records of all documents and correspondence pertaining to the project. 3.6 An engineer must be conversant with time and cost implications in the issuance of any instruction.	3.2 An engineer must not make wrongful certifications. 3.3 An engineer must not certify work not within his expertise. 3.4 An engineer must not accept site supervisory staff who are not qualified or are incompetent. 3.5 An engineer must not delay approvals without justification. 3.6 An engineer must not intentionally delay inspection of works.
<u>Regulatory Requirements</u> **Do's for Young Engineers**	 **Dont's for Young Engineers**
4.1 An engineer should notify the relevant authorities (within reasonable/statutory time limit) on changes in designs or withdrawal of services. 4.2 An engineer should submit completed forms in time for inspection and approval for Certificate of Fitness (CF)/ Certificate of Completion and Compliance (CCC). 4.3 An engineer should be aware of environmental, health, and safety matters during and after construction. 4. 4 An engineer should ensure that environmental, health and safety measures are implemented as per drawings and specifications.	4.1 An engineer should not allow works to proceed before plans are submitted to and/or approved by the relevant authorities. 4.2 An engineer should not undertake a project for which the client is not going to fulfill statutory requirements.
<u>Code of Ethics</u> **Do's for Young Engineers**	 **Dont's for Young Engineers**
5.1 An engineer must be conversant with the Code of Conduct of Engineers. 5.2 An engineer must understand the need for responsibility and liability as stipulated in the Code of Conduct. 5.3 An engineer must respond promptly to complaints and enquiries by clients/authorities	5.1 An engineer should no solicit/tout 5.2 An engineer should not knowingly mislead the public by giving misrepresented information so as to gain commercial advantage/mileage. 5.3 An engineer should not respond to an open advertisement to bid for provision of professional service if such provision for the service requires bidding fees or equivalent as is usually imposed on contractors. 5.4 An engineer should avoid favoritism among vendors and other suppliers.

MEASURING THE OUTCOME

Assessment of the engineering ethics criterion should be carried out using appropriately designed and tested student surveys, faculty surveys, employer surveys, and course exams. However, probably the most effective way to demonstrate most of the desired outcomes is through student portfolios that contain samples of student project report analyzing ethical issues with which a practicing engineer may be faced. These types of project report provide opportunities to demonstrate how a student applies knowledge of different ethical theories to make a decision on what the right thing to do is in a given engineering decision dilemma. Project report on ethical issues in the group project will also be valuable assessment instruments to include in student portfolios.

EDUCATIONAL APPROACH

Two main concepts, that are different from the main stream engineering ethics education, were introduced and emphasized in the course. The first concept focused on the existence of ethical thoughts and values that are different from western ethical thinking and are neither inferior nor superior to it. The second concept was that common morality and ethical standards might not be present in the same format between different cultures, but there are definitely a lot of common norms between these cultures. During the discussion of engineering ethics and the common ethical norms among different societies, the students were able to anticipate and state some of these norms, accompanied by relevant precautions.

During the course, students put moral reasoning on par with technical problem solving skills and communication skills. Also the students have been introduced to more tools to analyze moral problems, awareness of consequences of decisions, deeper understanding of professional responsibilities by reinforcing natural inclination to act honestly. Note in quotation “on and off the clock” – one is always a professional. For example, a civil engineer who sees unsafe construction practices, even on a project to which she is not assigned, is obligated to bring those practices to the attention of the appropriate person. In addition, engineering students are taught to “make the self invisible in problem solving,” students are acutely aware about their personal responsibility for the social consequences of their technical decisions. Consequently, this will improved moral reasoning (cognitive goal) of the students. However, knowing right answer does not mean choosing to do right thing. Hence, the students have been taught to be courage to make decision when face the moral dilemma.

Throughout the course, the students also understand that engineers have the power to create and control objects and system such as cars and aircraft; large interconnected systems such as electric power grid, sewage treatment plants, computer networks that are intended to improve the lives of people. Engineering courses demand the correct solution of technical problems; correct answers are required so that objects and systems will function properly. And people’s lives depend on their proper functioning. Therefore, engineers are morally responsible for safety.

The main conclusion they came up with was that a ethical situation involves multiple considerations and that a balanced approach should result mostly in common grounds solutions that will maximize benefits to all parties with the least possible compromise of the engineer’s ethical standards. More ideas and alternatives to approach certain problems in the profession were proposed by the students in their project report for the course with no right or wrong answer (open ended approach) to encourage critical thinking and courage to express ideas.

RESULTS AND DISCUSSIONS

Some of the papers produced by the students included interesting discussions and innovative thoughts on the topic. The topics selected were based on real questions on ethics during Professional Interview Examination from IEM and BEM. The idea is to expose the students with the real problems based on real questions of Professional Interview (PI) examination. These papers project the views of the students on some of the different topics that were discussed in the course, which are real issues in practicing engineering. The experience gained from introducing and discussing a presently critical issue, which is the engineering ethics, was enlightening to most of them but realistic to those who did face the issues already. The students must discuss the unethical issues in the report and relate to the Code of Professional Conduct of BEM. This was a different and new way of looking at engineering ethics. The students’ group project included very interesting and exciting topics like:

1. Engineering failures case study in Malaysia and relate to Code of Professional Conducts of BEM
2. Rights and responsibilities of engineers
3. Engineering ethics related to bribery and other unethical practices
4. Engineers’ role in modern policy making

5. Safety and Helath in Engineering project
6. Positive and Negative Contributions of Engineering Project related to Environmental Ethics

The main theme detected from the students' project report and presentations was their capability of incorporating the code of professional conduct and their appreciation of the magnitude it has in the practice of the profession. Some of these students stated that they will continue looking seriously at this issue after leaving the course to locate opportunities through which they can contribute to the advancement of the profession, from the ethics aspect, through their respective professional societies, or other means. Engineering ethics education is a necessary step in the direction of upgrading engineers' skills to practice in the real world. The ultimate goal is to ensure all future engineers to practice the engineering code of ethics and standards of practice. Consequently, this will enhance the image of engineering profession in the eyes of the public.

CONCLUSIONS

The outcomes indicate that most students after taking EIS subject will be more tactful in making decision when face with moral dilemma due to appropriate preparation to face these issues through EIS subject and highly appreciated having a course at university that would assist them to handle moral and engineering dilemma in future. The following are the observations made after the completion of EIS course:

1. Engineering professionalism can be developed for students in university through active learning and problem based learning.
2. Attitudes and skills required to prepare engineers for the profession, such as communication skills, teamwork, lifelong learning and ethics can be developed throughout the EIS course.
3. Students immersed in the PBL methodology experienced improvement in the understanding of engineering practices, mature into independent learners and inevitably developed problem solving skills.
4. Students have been educated with engineering ethics and professionalism especially the Code of Professional Conduct of Board of Engineers Malaysia plus the real unethical engineering challenges such as bribery.
5. Students understand the needs to uphold the integrity and dignity of engineering practice and act professionally in performing the duties despite the time, cost and management pressures.

By end of the course, most students understand the professional responsibility not only as liability for blame but in a capacious sense as stewardship for society. Hence, PEO No 2 is achieved and UNITEN will continue to generate professionals with strong ethical and professional background.

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