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Teaching ethics to engineering undergraduates – lessons learned and a guide for lecturers: perspective from an English University

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Abstract: The issue of ethics within engineering profession has been gaining more and more importance due to globalisation, increasing awareness of sustainability and the fast changing business culture within engineering organisations. As a direct result of such factors the accrediting bodies such as the IMechE and the ABET are very vocal about explicit ethics content in relevant undergraduate engineering programmes. However it is a very challenging exercise to deliver the topic in an effective way due to a number of reasons. First and foremost is the general reluctance of today's lecturers who themselves were not taught such topics and hence the vast majority are not very keen to consider such 'softer' topics very seriously. It is also difficult to accommodate the contents within the engineering curriculum which is already filled with various technical subjects. At the same time, a significant proportion of students find it difficult to relate ethics to real life working environment due to inexperience and hence would consider 'ethics' to be 'not so rigorous' a subject resulting in poor engagement. The present paper discusses the complete journey of how engineering ethics has been incorporated into an accredited BEng programme in Mechanical engineering. The three steps in course design i.e., breadth and depth of content, detailed planning for effective delivery and assessment and feedback – are all critically discussed by reference to available literature. The author also provides more than one pathway such that the experience may prove useful to the wider community

Introduction

Engineering ethics has been an important and well talked about topic for the past decade or so and a large volume of literature is available (Armstrong *et al*. 1999; Coby & Sullivan, 2008; Chung & Alfred, 2009; Fledderman, 2012; IDEA, 2012; OEC). Although the codes of conduct of any engineering company such as that of the SHELL UK (2012), has explicit mention of the requirement of 'ethical conduct within the organisation', it is fairly recently that the Royal Academy of Engineering (RAEng) of the UK, the UK's premier Academy of Engineering which brings together the country's most eminent engineers, have come up with the statement of ethical principles. Virtually, every single professional body within the engineering field such as the Institution of Mechanical Engineers (IMechE), the Institution of Engineering & Technology (IET) or the American Society of Civil Engineering (ASCE) – all have some common expectation for their members that they shall act in an ethical manner with due care to society, environment and natural resources. In recent years, the emphasis on engineering ethics has been steadily growing due to other factors such as globalisation (Chang & Wang, 2011), increasing awareness of sustainability and global warming (Hersh, 2000) and controversies around emerging technologies (Tait, 2011). The engineers of today are far more likely to experience the effects of these factors than their predecessors as is evidenced by the proliferation of articles published in various engineering education journals.

However, the very nature of 'engineering profession' renders ethics teaching relatively less focused in comparison with similar other professions such as Medicine or Law. In a strict sense, engineering as

a ‘profession’ is somewhat unregulated (Davis, 1998) due to the fact that a graduate engineer does not have to be a member of the relevant professional body, such as the IMechE, to qualify as a practising engineer. (For the sake of this paper, ‘engineer’ does not include people who can just ‘fix’ things. It is used mainly in the context of graduates or experienced apprentices or practitioners who are eligible for moving towards Chartered Engineer status). Doctors, pharmacists and legal practitioners, on the other hand, must obtain their licenses from the relevant professional bodies before they are even allowed to practise and hence are guided by the strict rules and codes of conduct. To the contrary, membership of engineering bodies renders someone to gain a Chartered engineer status which is no doubt an indicator of quality and status, but the professional body has very limited statutory power if the codes of conduct are breached. What they can exercise at most is to revoke the membership which is extremely rare. However, the professional bodies can and do exercise their power during the accreditation visits of the engineering departments. A non-accredited programme risks becoming unpopular and less attractive than their competitors under the current climate of higher education when the prospective students and their sponsors are more careful in choosing their institutions. It is not an overstatement to say that the accreditation process had been major driving force in raising the profile of ethics teaching in engineering. However, as outlined previously, the whole environment in which engineers tend to work has been changing fast and all speculations suggest that more changes are likely to happen in this direction (Lappalainen, 2011). It is perhaps relevant to highlight two important points in this context. First, engineers’ work especially in the sector of design (be it a system design or the design of an appliance) may have an impact on society or nature for a very long time. So the idea of an ‘informed consent’ as practised in medical profession cannot be applied for engineers. The other aspect is that the very nature of engineering practice does transform the ‘engineers’ to become other professionals such as managers with career progression. The level of engagement with other professionals can be so much in-depth that the identity of engineers, at least the way they are perceived in the wider community, gets blurred. Due to these facts, it is even more important for academic programmes to address the issues of ethics during the formative undergraduate years where the students will go through a systematic learning experience of ethics. As a teacher in engineering the author had gone through the whole experience for over five years and the objective of this paper is to document and critically appraise the whole process.

Available Guidelines

The Royal Academy of Engineering of the UK has come up with a curriculum map (RAEng, 2012) about ethics teaching in undergraduate curriculum. It shows how ethics can be taught over a four year MEng programme in a gradually deepening sequence and provides suggestions about which learning outcomes can be met at which level. However, given that the engineering curriculum is already filled with various technical subjects, it is very difficult to add contents of ethics which are different from the highly structured and deterministic style of engineering syllabus. Situation is further complicated for three year BEng programmes typical of most universities in England and Wales. With the modularisation of the subjects it has become even more difficult to design a compulsory core module on engineering ethics. To appreciate the expectations of RAEng and IMechE in terms of ethical awareness of engineers, exact wordings from these two organizations on ethical awareness are shown in Table 1. The learning outcomes from ABET are also included for comparison.

Table 1: Comparison of ethical expectations from different organisations

RAEng Expectations	IMechE expectations (Specific learning outcomes up to BEng level)	ABET 2000 (Learning Outcomes)
• Understand the nature of professional responsibility • Be able to identify the ethical elements in decisions • Be able to address and resolve problems arising from questionable practice • Develop critical thinking skills and professional judgement • Understand practical difficulties of bringing about change • Develop a professional ethical identity to carry forward in their working life	• Understanding of the requirement for engineering activities to promote sustainable development • Awareness of the framework of relevant legal requirements governing engineering activities, including personnel health, safety, and risk (including environmental risk) issues. • Understanding the need for a high level of professional and ethical conduct in engineering.	• An understanding of professional and ethical responsibility. • The broad education necessary to understand the impact of engineering solutions.

It is fairly obvious that the RAEng and IMechE expectations are very similar while ABET is a bit more generic but may be interpreted that the items in columns 1 and 2 are implied or embedded. Various proposals are available in literature for example, Catalano (2006), which proposes a slightly modified version of ABET to promote peace in engineering education. A further analysis of the IMechE learning outcomes shows that the items mentioned in the second column are to be met by the BEng programme. Interestingly, the MEng learning outcomes do not include any more item in terms of social and environmental context. Additional specific learning outcomes for MEng in the context of social, environmental and professional skills are related to strategic and tactical issues of business. This observation further highlights the importance of incorporating ethics earlier in the curriculum i.e., within the duration of the BEng programme.

The three steps

The three important steps that must be considered very seriously before incorporating ethics into the curriculum are: (a) breadth and depth of the content, (b) detailed delivery plan and (c) assessments. The fact that ethics is so far removed from the bulk of the engineering topics, it is very tricky to ensure that the right amount of content is selected and delivered appropriately to the students. Assessment is also important for students to appreciate its importance and at the same time to quantify the level of engagement within the curriculum.

Step 1: Decision on the ethics content

No matter how much time within the curriculum is allocated for the ethics content, there should be a balance between the theoretical and practical aspects. As Bouville (2008) points out ‘it is not a question of whether to use (ethical) theories but rather how to use them, in particular, whether to mention them explicitly.’ Engineering ethics, although part of the ‘applied ethics’, is a branch of philosophy and the contents, irrespective of how big or small or for whoever group of students it is directed to, must have the right flavour. What is meant by this is that engineering ethics is still ethics and cannot be taught/taken too lightly i.e., presenting in such a way that it is just ‘commonsense’. This approach will take the rigour out of the content and may appear to be ‘a time waster’ or ‘time better spent on doing thermodynamics problems’ to a significant majority of learners. The other approach to avoid is to take a very engineering or too deterministic approach to a dilemma, although both students and academics are very comfortable with such approach. However, this is fundamentally flawed. The notion of teaching ethics is to open up the thought process of learners for more than one solution, be imaginative about ‘what would have happened if..’ kind of questions. It is therefore quite critical to make the appropriate balance between theory (Gunn & Vesilind, 1986; Spier, 2001) such as

Utilitarianism, Kantism, rights , virtue and codes of conduct of the organisation and commonsense or value judgement. A suggested curriculum content may include the following items.
(a) Statement of ethical principles, company code of conduct, professional obligations to society.
(b) A brief introduction to relevant ethical theories.
(c) Some reference to textbook case study such as the Challenger disaster (Pinkus et al., 1997) and reference to common practices such as 'pirated software' – to use or not to use.
(d) Relationship between ethics, law, company code of conduct and health & safety regulations.
(e)How to handle dilemma and the importance of having more than one solution and the critical justification for various options.

Step 2: Planning for detailed delivery

Since the time allocated for the explicit ethics content is likely to be very limited, it is essential that the detailed planning of the content and delivery is taken very seriously. The following three items appear to be vital.

Who will deliver?

Most academics in UK universities within the engineering programme have not been through any amount of ethics study. The knowledge they have are mainly from common sense or through experience which is very similar to any other lay person in other professions. Perhaps, somebody who wants to take a challenge and go beyond the comfort zone of engineering subjects would be ideal.

There are two reasons why this issue needs special consideration. One, this is a topic which is 'easier said than done' and second no matter how enthusiastic the person is, it is still regarded as a 'second grade' subject to most engineering academics as well as to a large number of students. This is a note of caution for whoever wishes to do the job, but at the end of the day, the main reward is perhaps personal achievement and the confidence.

Which module(s) to consider for ethics inclusion?

As mentioned before, the current three-year frame work of BEng programme for English universities does not provide enough room for a stand-alone ethics module. Also, it is the author's observation that there are two major practical hindrances to run an ethics module on its own. Firstly, it is uncertain whether such a module would attract enough interest of students and be viable and secondly it would be very difficult to find an engineering lecturer to deliver such a module.

The next issue is to choose suitable modules within the programme where ethics content can be incorporated as bolted-on, integrated or embedded (Chadha, 2006; Davis, 2006). One approach would be to look at the whole syllabus to be comprised of four thematic divisions, namely, Design, Energy Studies, Mechanics and Others (which include Professional Skills, Economics, Accounting, Business etc). A thorough review of the four areas is necessary to identify the modules where ethics component as chosen in Step 1 can be added at various levels in a progressively deepening sequence. A suggested way would be to choose either Design or Energy Studies subject areas and use the coursework component wholly/partially dedicated to ethics. This would make sure that ethics is explicitly incorporated with a clear summative assessment. Depending on the choice (either design or energy), suitable case studies may be selected. However, it is also possible to deliver the contents through more than one subject area given that more resources are available.

How and When to deliver?

Depending on how much time can be allocated for the ethics teaching and the class size, the delivery mode can be highly variable. Literature (for example, Rowden & Bradley, 2004) suggests that the teaching method should be a combination of lecture, tutorial session and case study presentation. Many other different approaches have been tried, the most spectacular one is through drama (Monk, 2008). However, it needs to be recognised that large class sizes are a limiting factor for some innovative methods. The availability of the discussion board through e-learning portal such as Blackboard, available in most academic institutions, allows another platform to deliver the topics. The idea of PBL (Zandvoort *et al*., 2008) may also prove to be relevant for ethics because it promotes active learning and enables students to make substantive connections with course contents.

The following brief guideline may be useful for anyone planning to take the responsibility of teaching ethics to engineering students. The whole content may be delivered via a combination of the four items mentioned below:

- Formal lecture: This may comprise the five points identified in Step 1. The lecture content may also be split between different levels as shown in Option B in Table 2.
- Application of ethical theories and principles in the context of:
  - Fictitious but realistic case studies available from various sources (IDEA 2012; OEC, 2012) or concocted by the tutor.
  - Case study based on student's own work in design or energy studies
- Presentation and discussion of case study: Either by groups of students or the tutor himself
- Embedding ethical consideration in the final year individual project or dissertation.

Table 2: Delivery options

Option	Level 5 (Year 2)	Placement year (Optional)	Level 6 (Year 3/4)	Assessment method
A	Professional Skills module covers sustainability but not ethics		• Identify a suitable module (e.g., Energy studies or design) • Formal lecture comprising all 5 components • Case studies taken from various sources or formulated by the lecturer • Completion of ethics form in individual project	Group presentation and Individual essay
B	Professional Skills module covers sustainability. Statement of Ethical principles, company codes of conduct etc. taught here Some assessment on ethical principles through group presentation and/or essay		• Identify a suitable module (e.g., Energy studies) • Formal lecture comprising only 4 components • Case study based on an actual energy audit and ways to improve energy use by reference to ethical sources. • Completion of ethics form in individual project	Individual essay

The correct timing is also critical from the viewpoint of student engagement. Since the topics are very different in style, it should be delivered at a time when students are not pre-occupied with other assignments on so-called 'hard topics' and/or project work. A suggested timing might be the beginning of the autumn term when the students are joining the year after the summer break or returning from placement. It is likely that during the first four weeks, students will have very few submission deadlines and hence would be able to engage. The only drawback is from lecturer's perspective that he/she may find it difficult to make time for marking and feedback. Delivering ethics before Christmas break may be convenient for assessment but students may not be able to engage due to submission deadlines for other technical subjects.

Step 3: Assessment and feedback

It is very unlikely that the assessment for this type of topic can be through a closed book examination typical of engineering subjects. A convenient assessment method should be an essay and/or presentation. Very serious attention needs to be given for the particular choice of component. The accrediting bodies such as the IMechE are very keen to see some sort of summative assessment. The other reason to support the need for an assessment is that the students did not find it 'very easy to write' and discuss the case studies as will be shown later in the paper. One interpretation by the author (also supported by students) is that, it is only when the students started to analyse the case studies seriously than they could appreciate the difficulty and felt that it is much more than a 'common sense'. Had there been no assessment, students would have left the programme without really giving a serious thought to ethics. The individual essay can be an ethical analysis about case studies given by the tutor (option A) or about their own work generated during another assignment by the students themselves (option B).

Group presentation can be a very useful and interesting way of assessment. Each group may be assigned a particular case study on which they can make a presentation in front of fellow students.

The follow up discussion is likely to enhance peer learning. One of drawbacks is that, this may prove to be very time consuming with larger cohort of students.

Similar to other subjects, it is important to get feedback from students to know what changes should be made for future delivery. One suggestion for the feedback questionnaire would be to include few questions about the respondent's age group, gender, mode of study and ethnic origin. The author has observed a distinct pattern in answers depending on the student's background. For example, almost all of the part-time and mature students answered 'yes' to the question of 'whether ethics is important or not', while only half of the full time students said 'yes'. Table 3 below lists the most frequent qualitative comments collected over the past five years by the author himslef.

Table 3: Selection of common qualitative comments

Most enjoyable aspect	Worst point
• A break from the mathematical side of engineering • Having group discussion where everyone participated • The discussion in and out of the class • The debate about personal judgement and decision making processes • Understanding how ethics fit into engineering	• Difficult to write the essay. • Case study not specific enough – information is not enough • Not very technical and too much conceptual theory involved in it • Takes mind away from examination related topics • Too short time allocated for the topic

Discussion

Between the two options mentioned above, option A can be easily adapted by taking help from a rich volume of available resources, for example, IDEA; OEC. However, their use for the purpose of assignment does not prove to be so straightforward due to the fact that numerous websites contain follow up discussion on almost all case studies. To avoid plagiarism and to ensure that the students are really engaged, the alternative would be to create a set of new case studies. On the other hand, option B seems a better choice because the 'exercise on actual energy audit' will be conducted by the students themselves and hence they can be more imaginative to 'explore alternatives'. A common feedback from students is that there was not enough information in any of the case studies (Table 3) on which they were required to write an essay. This is probably due to the thought process of engineering students who prefer to seek a 'deterministic' or 'unique' solution to problems. However, by the time the students reach their final year, expectation by the professional bodies is that they should be more adaptable with variation and should be able to relate with 'other engineering or related disciplines' and hence the detailed analysis of ethics case study is immensely helpful in this context.

The fact that the class cohorts in most UK universities are highly heterogeneous, an example shown in Table 4, is very useful from the viewpoint of teaching ethics. The initiation of a lively discussion is the single most important pre-requisite for a successful delivery. Until and unless the students start to participate in discussion, the teaching may appear to be extremely boring as well as frustrating for the lecturer and students may not engage at all. The part time and mature students may act as catalysts in initiating the discussion. The simple reason for this lies in the fact that the mature students and those returning from placement can see the relevance very easily. The cultural diversity and differences in moral values (Eckensberger, 2003) may contribute significantly to the variation of opinions. The tutor, however, needs to remain vigilant to make sure the discussions are kept within allowable norms and no one is offended.

Table 4: Cohort analysis of 40 students (Academic Year 2008-09)

Mode of study	Full time: 32	Part time: 8	
Domicile	Home: 30	Overseas: 10	
Job experience	>2 years: 12	1-2 years: 15	<1 year: 13
Gender	Male: 36	Female: 4	
Age	Below 25 years:28	Mature: 12	
Ethnicity	European: 27	Asian: 8	African: 5

Group presentation can be made very lively and interesting by a careful composition of the groups, for example, by making them as heterogeneous as possible. The main difficulty with group presentation is that it is very resource intensive. The time and effort needed for the exercise can be very significant and should be carefully considered.

The author has observed that the average mark for the ethics component varied between 62 to 65 percent over the years with a small standard deviation, as expected. About 70% of the students were satisfied overall, 20% were neither satisfied nor dissatisfied and 10% were dissatisfied. The total contact time was six hours with a notional student workload of 20 hours. About 80% thought that the time allocated was just right and the rest suggested that more time should be allocated.

Conclusion

The paper highlights the practical issues related to incorporating ethics into the Mechanical engineering programme in an English university. Two different options have been tried and proposed with the possibility of having further flexibility in the design and delivery of the content. The issues raised in this paper are believed to be useful to any prospective lecturer who is either teaching or planning to teach ethics in engineering or other related discipline. Some of the experiences may well be compared with those from other institutions and may help improve or modify the practices. What is not covered in this paper is how effective and important the ethics content proved to the graduates after they have left the university and started working. Some initiatives are already in process to collect general feedback from ex-graduates. However, conducting a thorough evaluation would be dependent on time and resources.

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