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INTEGRATING ENGINEERING ETHICS AND RESEARCH SKILLS IN A FIRST YEAR PROGRAMME

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ABSTRACT

A first year module which introduces students to the social dimension of engineering is described. The key teaching tool is the use of group projects to develop students' learning skills. The importance of addressing the motivation for engineering students studying non-technical modules is emphasised. Data used to evaluate the module is presented. It is shown that the nature of the project undertaken affects the attainment of learning outcomes. The conclusion focuses on some shortcomings of the module and highlights the importance of appropriately structuring the learning environment to facilitate self-directed learning by early year students.

INTRODUCTION

Current debates about educating engineers have focused on the need for what is called the 'New Engineer' [1, 2]. The demand for the 'New Engineer' is reflected in changing approaches to the accreditation of professional engineering programmes. Like professional bodies in other countries Engineers Ireland (EI), previously known as the Institution of Engineers (IEI), has changed the accreditation criteria to include learning outcomes focused on 'ethical standards', 'responsibilities towards people and the environment', teamwork, lifelong learning and communication. [3: 11-12] EI has identified six areas of study including the *Social and Business Context***.** Engineering programmes are required to 'develop an awareness of the social and commercial context of the engineer's work'.

There is a growing literature examining how engineering faculties can contribute to the broadening of engineering education [4]. This paper will describe a first year module which attempts to broaden the education of engineers. The module focuses on the social context in which engineers work and through the use of group projects helps student to develop their research and communication skills while at the same time developing their understanding of engineering as a social, as well as a technical, process. As such it focuses on key learning outcomes identified by EI.

I will proceed as follows. Firstly the rationale for the module is discussed. This is followed by a description of the module. Data collected to evaluate the module is then presented followed by some reflections on developing the module in the future.

RATIONALE

Given the restrictions of space it is not possible to review all the debates that arise in relation to the new engineer but we can identify two main rationales behind the demand for the new engineer [5 includes a bibliography of some of the literature]. The first centres on the need to enhance the skills of engineers highlighting the importance of acquiring non-technical generic competencies in areas such as communications, project management, leadership and teamwork. These skills are required to make engineers more effective as engineers and also because, they spend much of their working lives on management and supervisory tasks. This emphasis on generic professional practice skills can be seen as a response to changes in the organization of work resulting from increased global competition [4] and new forms of work organisation [1: 19].[1] The demand for new skills can be seen as part of a broader agenda in higher education focusing on what is called employability.[2]

The second focuses on the relationship between engineers and society. It is acknowledged that engineers have a profound effect on society and there is concern that the status of engineering is being undermined as engineers are identified with environmentally damaging technologies [2]. There is also concern that this could affect the willingness of young people to study engineering. A recent report from the Royal Academy of Engineering states: 'The social responsibility of engineering is an important issue underpinning attitudes towards the profession' [6: 38]. Thus engineering ethics assume importance.

In the context of engineering ethics the issue of sustainability poses a particular challenge. Many codes of ethics, including the code of EI, contain a commitment to practice and promote the principles of sustainability and while engineers are seen to be central to developing sustainable solutions many of them tend to have a narrow view of sustainability, a view that is shared by engineering students [7]. Some have argued that sustainability 'implies cultural, social and economic restructuring simultaneously with technological restructuring' [8: 150]. Sustainability is not jut about developing appropriate technology but also requires a focus on the political, economic and social arrangements within which technology is developed and used.

Taking this into account what follows is a brief outline of the overarching approach that informed the development and structure of the module. This is being done to highlight the importance of developing a clear rationale both for staff and students as to why they need to do the kind of work that is covered in the module.

My approach is informed by three key concerns:

1. Engineering is a social process.

Engineering always takes place in a social context; it affects human relationships and involves political and ethical choices [9]. It follows that engineering ethics is not just about the values of individual engineers but must also focus on the context of their work and whether it constrains or enables a socially responsible engineering practice [5]. A focus on both micro and macro issues is

[1] It is regrettable that this focus on the workplace does need lead to a fuller consideration of the role of engineers in designing work for others [see 5].

[2] Employability has been defined as *'a set of achievements – skills, understandings and personal attributes – that make graduates more likely to gain employment and be successful in their chosen occupations.'* by the UK Higher Education Academy, Engineering Subject Centre. See http://www.engsc.ac.uk/er/employability.

needed to adequately address the ethical responsibilities of the profession. The recent focus on sustainability underlines the need to integrate macro issues into the curriculum [10].

This involves a focus on broader social processes and the regulatory environment in which engineers operate. The traditional approach to engineering ethics has focused on case studies and the posing of individual moral dilemmas [11]. While case studies are used within the module (mainly as a tool to emphasise the importance of public safety and to familiarise students with the EI code) the key learning tool is a set of group based projects which focus on social issues and the public image of the profession. In the main the focus is on real world problems [12].

2. Learning and research is a social process not a discreet set of fragmented tasks.

There has been some debate on how to develop the learning skills of engineering students [4, 13]. The key distinction is between embedded and bolted on approaches. With the latter approach that skills are developed independently of core course material through specific modules focused on communications, study skills or group work. While there is explicit reference to the development of transferable skills this approach is problematic as students often fail to grasp the academic value of modules divorced from their overall teaching and learning experience [13]. This tends to lead to disengagement and the constant questioning of the relevance of these modules to engineering. A further problem is that students are often assessed on their ability to carry out a set of discreet tasks such as writing a report, doing a presentation or using the library.

With the integrated approach 'skills are developed and taught explicitly within the core discipline and the same amount of emphasis is placed on the development of transferable skills as technical abilities' [13: 21]. Explicit reference is made to the value of developing such skills and opportunities are provided for students to reflect on their abilities and hopefully develop. This seems particularly important given the emphasis on examinations and the recitation of facts in secondary school education.

The focus in the module is therefore to integrate learning skills as part of a process of examining a real world engineering problem linked to the course content. This encourages the students to engage in problem solving and see learning as an integrated process involving defining their problem using concepts presented in the lectures, devising a strategy for collecting information to help them solve it, collecting and evaluating the information they find, arriving at conclusions and recommendations in light of their objectives and presenting these to others. The benefits of group work have been well documented [19]. By working in a group they see that learning can be a collaborative process.

The emphasis is on structuring the learning environment so that students have to engage on an ongoing basis with their project. This is consistent with a growing emphasis on active learning in the engineering curriculum [14].

3. Student motivation needs to be explicitly addressed

Reflecting on many years work in trying to broaden the education of technical or vocationally oriented students I have come to see the importance of explicitly addressing the issue of student motivation particularly for early year students. This requires a focus on where the students are now rather than where they might be when they graduate. It involves an explicit focus on the

various dimensions of engineering practice and an understanding that many engineering students tend to be active rather reflexive learners [15] and that early year students tend to have a 'sensing mode of perceiving' which emphasises the concrete, practical and the immediate. Such students tend to learn better using a practice-to-theory approach rather than the more traditional theory-to-practice route [16].

In general my concern is not to focus narrowly on employability but rather to broaden the students understanding of what makes a good engineer whilst at the same time developing learning skills. It is assumed that social responsibility is central to good engineering practice [9]. Thus students should be introduced to key ethical issues in the first year of their studies so that they come to see them as inherent to engineering and come to see engineering as a social as well as a technical process.

THE MODULE

The module is a 5 credit module in Professional Development (PD) delivered to the Common First Year (DT025) in Engineering in DIT, Bolton St. Typically there are 120 students who have in excess of 400 points based on their Leaving Certificate scores. The class is predominantly male with females numbering between ten and fifteen every year. The module has been in place for many years as part of a suite of General Studies modules provided within the faculty. These modules tended to cover a wide range of often unrelated topics.

I have been teaching the module for four years and it has evolved from two one hour lectures a week to one hour lecture plus a workshop/tutorial. The class is divided by eight for the purposes of the workshops which are conducted by myself and another lecturer. The module runs over two semesters. Assessment is divided evenly between an exam and course work. The latter involves an individual report written by each student and a group presentation.

The lecture programme covers three broad areas:

1. The nature of engineering and the requirements of the New Engineer. Given the importance placed on student motivation above students are given an opportunity in the first four lectures to explore the reasons why engineers need a broad range of knowledge and skills. A wide range of research findings are presented to students and the impact of engineers on society are explored. Students are required to read the introduction to Beder's *The New Engineer* and write a summary before this sequence of lectures ends. This is used as an opportunity for us to evaluate the general writing skills of the students.

2. Engineering and society. Key themes covered here are the nature of communications, the public image of engineering, engineering ethics and principles of sustainability.

3. Engineers in organisations. This section of the course looks at issues within organisations including employment relations.

The workshops run alongside the lectures and are used to help the students complete a group based project on one of the themes outlined in Table 1.

While the projects are on specified topic areas it is left open to the students to define their own objectives and decide on the actual content. Each group are asked to produce a number of pieces of work:

1. An outline plan and a reading list
2. An individual reports covering the topic area. This is used to illustrate their background research and to allow us assess their writing skills. This is completed at the end of semester 1.
3. A group presentation using Power Point. This is done towards the end of semester 2.

Table 1: The Group Projects

1.	The Department of the Environment is worried that engineers are not taking the threat of Global Warming seriously. It asks your group to prepare a presentation to convince engineers that it is a serious problem and that they have a responsibility for it. You are also asked to suggest some ways in which engineers can reduce global warming.
2.	Engineers Ireland is concerned that engineering students do not take engineering ethics seriously. They ask you to produce a presentation which will convince engineering students that ethics are essential in engineering.
3.	The Green Party is concerned about the damage that engineers are doing to the environment. It asks your group to produce a presentation, for presentation to engineers, highlighting the environmental damage caused by engineers and suggesting ways engineering could be more environmentally friendly.
4.	Engineers Ireland is worried about the image of engineering. It asks your group to prepare a presentation highlighting the positive contribution engineers make to society. It wants your group to highlight aspects of engineering that might attract more women to the profession. The presentation is to be given to secondary school students.
5.	Engineers Ireland is worried that many engineers do not have the necessary skills to be successful in their profession. It asks your group to prepare a presentation for employers highlighting the skills needed for the New Engineer. It wants also asks you to suggest how engineers might acquire these skills.
6.	Dublin City Council is in despair about the traffic problems in Dublin. It asks your group to prepare a presentation for engineers suggesting how they might contribute to solving the problem. It asks you to clearly identify which branches of engineering can make the biggest contribution to solving the problem.
7.	The Environmental Protection Agency is concerned that engineers do not fully understand the concept of Sustainable Development. Your group is asked to produce a presentation explaining sustainable development and the role engineers can play in supporting sustainable development. Your presentation is to a group of older engineers.

Each group is also asked to keep a minute's book and draw up a list of ground rules shortly after the group is formed. Group formation is based on students completing the Belbin test for group roles. It should be noted that educating the students about teamwork is not the central objective of the module. Rather groups are used as a convenient way to manage the large number and also to introduce the students to collaborative learning.

In the course of the workshops each group is also assigned an ethics case study which they present to their workshop group. These are focused on public safety and also address issues to do with working in organisations. The students are asked to apply the EI code of ethics to the case study. These presentations are short and serve a role in giving the students an opportunity to do a presentation, often for the first time. Students are not marked on the case study presentations but participation is compulsory. Those who do not attend have a 10% reduction applied to their

overall mark for the project work. The sequence of the workshops as run in 2007/8 is presented in table 2.

Table 2: The Workshops

<table>
<tr><td>Week3</td><td colspan="2">Introduction</td></tr>
<tr><td>Week4</td><td colspan="2">Group Formation: Belbin</td></tr>
<tr><td>Week5</td><td colspan="2">Project Planning : Stages in Doing a Project</td></tr>
<tr><td>Week6</td><td colspan="2">Information Retrieval: Using the library</td></tr>
<tr><td>Week7</td><td colspan="2">Review Week</td></tr>
<tr><td>Week8</td><td colspan="2">Making Groups work: Ground rules</td></tr>
<tr><td>Week9</td><td colspan="2">One from each Group to report on objectives and outline</td></tr>
<tr><td>Week10</td><td colspan="2">Referencing and Plagiarism</td></tr>
<tr><td>Week11</td><td colspan="2">Report Writing</td></tr>
<tr><td>Week12</td><td colspan="2">Report Writing: Sample</td></tr>
<tr><td>Week13</td><td colspan="2">Review</td></tr>
<tr><td colspan="3">Christmas</td></tr>
<tr><td>Week1</td><td colspan="2">Presentation Skills</td></tr>
<tr><td>Week2</td><td colspan="2">Presentation Skills/Report Feedback</td></tr>
<tr><td>Week3</td><td colspan="2">Using PowerPoint</td></tr>
<tr><td>Week4</td><td colspan="2" rowspan="2">Ethics Case Studies
Ethics Case Studies</td></tr>
<tr><td>Week5</td></tr>
<tr><td>Week6</td><td colspan="2" rowspan="2">Work On Presentations
Work On Presentations</td></tr>
<tr><td>Week7</td></tr>
<tr><td colspan="3">Easter</td></tr>
<tr><td>Week8</td><td rowspan="3">Presentations</td><td rowspan="3">All of relevant group to attend</td></tr>
<tr><td>Week9</td></tr>
<tr><td>Week 10</td></tr>
<tr><td>Week11</td><td colspan="2">Feedback</td></tr>
</table>

As can be seen from table 2 all stages in completing the project are covered in the course of the workshops. The module is also supported by:

1. A WebCT site which includes lecture and workshop support material but also has a projects area with readings and links related to each project topic. This has grown from year to year as students find new and useful sources.
2. A specially designed interactive session on using the library.
3. A dedicated Guide to Report Writing. Students are required to use the Guide and sign a pledge saying they will not engage in plagiarism.
4. Clear instruction sheets for each task.
5. Extensive individual and group feedback.

EVALUATION

In this section results of a survey completed by 85 of the 115 2007/8 students (a

response rate of 74%) are presented along with some reflections. Table 3 presents data from students on the extent to which the module helped them in relation to a number of learning outcomes. Responses were based on a five point scale with 1 being a little and 5 being a lot. Responses are ranked from the lowest to the highest.

Table 3: Evaluation of Learning Outcomes

	Mean n=85	**Std. D**	**Male n=72**	**Female n=13**
Find information in the library	2.86	1.07	2.96	2.31
Understand the principles of sustainable development	3.05	0.96	3.07	2.92
Working in a group	3.13	0.90	3.17	2.92
Reference information properly	3.33	1.05	3.35	3.23
Do research	3.39	0.93	3.46	3.00
Understand the role of engineers in society	3.55	0.88	3.57	3.46
Do presentations	3.73	1.03	3.71	3.85
Understand ethical issues in engineering	3.73	0.91	3.74	3.69
Write reports	3.74	0.92	3.81	3.38

The following issues arise from the data:

1. It can be noted that in all cases the means for males were higher than for females except in one instance: 'doing presentations'. The differences though were not statistically significant.

2. It can be seen that the highest scores were related to understanding ethical issues in engineering and writing reports and doing presentations. This is not surprising as these three issues are given most prominence in the module. All students do a presentation on an engineering ethics case study. In open-ended responses students were most likely to say that these three items were either the 'most interesting' or the 'most useful' part of the module. Indeed in the questionnaire a number of respondents suggested that they should be given more opportunities to do presentations.

It is worth noting that outcomes related to the end product of the process, reports and presentations, score better than those to do with the process of doing research, finding information and working in a group.

3. Those that scored lowest were related to using the library and referencing, working in a group and understanding the principles of sustainable development. This again is not surprising. Although the students are given a comprehensive introduction to the library it is the case that most of the research they do is web based. It may be the case that they are using the library's online resources without ever being 'in the library'.[3] The WebCT site also contains a lot of reading material.

4. The issues related to working in a group are a difficulty which needs to be addressed. In an open-ended question on the questionnaire some students indicated a need to deal with 'slackers'. Given the numbers in the module it is proving quite difficult to arrive at a system for successfully monitoring the activity in the groups. When difficulties are brought to the lecturers' attention they

[3] The wording of this item is problematic given the changing role of the library and its function as a portal to various online resources.

are addressed. Minutes books have been taken up and examined but do not seem to adequately reflect the differential effort put in by different students. It is the case though that when it comes to evaluating assessments it is clear who has and who has not done the work. Students get an individual mark for their report and a proportion of the group presentation marks are assigned for individual contributions. Extensive questioning at the end of the presentations also helps with finding out who has done most.

As indicated above educating students about teamwork is not a key objective of the module. But the students on the module do work in groups and the issues noted above are common problems associated with facilitating groups [20,21]. Therefore it is important that we explore ways to improve their experience of working in a group by facilitating 'positive interdependence' [20].

5. The final item where the mean was relatively low was 'Understand the principles of sustainable development'. This is perhaps one of the most difficult sections of the lecture programme. It also does not help that attendance at lectures is low with on average only 50% of students attending each lecture. (There are only minor problems associated with attendance at the workshops).

Significant differences on this item and on the other substantial knowledge outcome, 'Understanding ethical issues in engineering', were recorded when the means were compared based on the project that the students had completed.

In relation to sustainability the two projects focused on sustainability and the environment (projects 7 and 3 in table 1) had significantly higher ($p=.05$) means than most other projects particularly those focused on the 'Image of engineering' (project 4) and 'engineering skills' (project 5). Surprisingly there was also a significant difference between those who has done the environment project and those who had done the project on global warming (project 1) or the ethics project (project 2).

In relation to the ethics outcome the highest means were for students who had done either the ethics (2) or environment (3) project. In the case of the ethics project the means were significantly higher than the means for all other projects. In the case of the environment project the means were significantly higher than all other projects except for the traffic project (6).

It is worth noting that some of the best projects were those completed by groups doing projects 2 or 3. These groups showed a greater ability to integrate theory from the lectures with the information they had gathered to complete their project.

6. It is worth noting that 86% of respondents said that the module 'helped them to understand what engineering is' while 56% said it 'changed their understanding of engineering'.

DISCUSSION

This module provides a significant opportunity to first year engineering students to develop their research and learning skills while at the same time gaining an insight into engineering as a social process which involves ethical issues. As part of a process of completing a group project students complete a number of assessments aimed at encouraging them to engage in independent self directed learning. This module represents a significant development in the broadening of the first

year education of our engineering students. The extent to which the module works is related to the manner in which learning skills are embedded and engineering issues and student motivation are addressed directly.

While some shortcomings of the module have been highlighted above I want to conclude by addressing two key issues which arise from the data and from my own reflection on the operation of the module over a number of years.

Firstly it has been seen that there are differences between students, depending on the project they completed, in the extent to which they believe they have acquired an understanding of ethical issues in engineering. This is a key learning outcome of the module. Some projects seem to be less successful in helping students meet this learning outcome. Two projects in particular, 'Image of engineering' (project 4) and 'engineering skills' (project 5), scored relatively poorly on the two substantial knowledge outcomes relating to ethics sand sustainable development.

There is a sense that the module is carrying some baggage from its origins as a General Studies module which often had multiple (if sometimes undefined learning outcomes). This is a reflected in the wide range of topics covered in the lectures and consequently by the projects. It was hoped that projects focusing on the skills of engineers and the image of engineering would force students to exam the ethical dimensions of engineering but this has not happened to the extent expected. The students do see, for example, that the kinds of problems engineers solve and the manner in which they solve them affects the image of engineering. What they do not see is how ethical issues are implicated in these choices.

It also seems to be the case, particularly with the project on Global Warming and to a lesser extent the project on traffic, that projects focused on contemporary issues may be approached as purely factual projects without the need to integrate theoretical issues raised in the lectures. The students do not, for example, see the need to situate the information they gather about Global Warming in wider discourses about sustainability and social responsibility. Further, the students do not see the need to argue for proposed solutions and present evidence as to why one solution is better than another.

Secondly, this points to what I perceive as a difficulty the students have in engaging in self-directed learning. Part of this problem is their failure to read systematically around their topic and as suggested above integrate theory into their projects. This has something to do with their experience of secondary education [22], that fact that many engineering students are active learners and with the nature of the knowledge students, particularly first year students, engage with in engineering programmes. In scientific and mathematical modules they tend to learn that there is only one right answer to the problems they are set [19: 65, 14: 351]. The material dealt with in the PD module is of a different character. As Porra says, in discussing engineering ethics: 'The inexact and relative nature of some of the concepts in these subject areas is in conflict with the "exact" world of technology' [18: 337]. The students may therefore find it harder to manage their learning in this module and know what amounts to a 'right answer'. Their focus is very much on gathering information rather than integrating knowledge and information.

In light of these two issues there is a requirement to firstly reconsider the project topics and the lecture programme and develop new projects which will raise ethical issues more clearly and secondly, to be more directive in terms of what students need to do to complete their projects

successfully. More effective goal setting may help them manage their learning better [22]. This will include a much clearer requirement to situate their project topic in the context of the lecture material. This will require greater attendance at lectures. It may require that they read set readings rather than searching widely for material of variable quality. It might be the case that by more tightly structuring the learning environment the students may learn to be better independent learners.

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