Teaching engineering ethics and sustainability

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Abstract

Most professional engineering code's of ethics require that engineers shall understand and promote the principles of sustainability and/or sustainable development and have due regard for their environmental, social and economic obligations. However the ethical obligations towards sustainability are incorporated into the teaching of engineering ethics in very few programmes. Typically engineering ethics is taught via relatively straightforward case studies whereby students are asked to identify with a particular individual agent acting alone and determine the correct or optimum course of action. Context, complexity and an interdisciplinary approach tend to lose out to objective reality in such scenarios.

This paper describes the teaching of engineering ethics as part of an introductory first year undergraduate module. Students were presented with the real life wicked problem of matching future municipal water supply and demand in Dublin. They were asked to consider the published findings of an engineering consultancy group and then propose and present their own recommendations. This approach was employed to introduce a number of sustainability concepts in the context of professional ethical responsibility while developing their critiquing skills. The paper reflects on the outcomes of this exercise, including the students' own assessments.

Teaching engineering ethics – current practice

The typical means of teaching engineering ethics in professional programmes reflects the values and perceptions of both engineers and engineering educators, that is, that engineering is somehow a 'value free' profession [1] which seeks to establish 'objective' criteria in making decisions and solving problems, including ethical ones. Ethics is therefore taught through the individualistic object world of the engineering profession [2] where the broader context is ignored [3], and the teaching of ethics reflects this though case studies which focus on microethical issues where students are encouraged to role play and reconcile ethical dilemmas involving individual actors. Such case studies encourage students *"to express ethical opinions, ..to identify ethical issues and formulate and effectively justify decisions"* [4]. Other characteristics of this approach include a framework based on professional codes of ethics and an assumption that win–win solutions always exist and can be implemented by individual engineers [3]. The interplay between the individual and the organization is sometimes examined in this context, but rarely is the broader super-organisational world of public policy, society, governance or the greater good invoked. For it seems this is not the role of the engineer! As the UK Teaching of Engineering Ethics Group [5] suggested:

> *"A typical perception that engineers 'do engineering' whilst others have the prime concern with the implications is erroneous and based on an overly-narrow view of the role of the professional engineer often held by engineers as well as by others"*

Others concur with this view. Herkert [4] has pointed to *"the traditional preoccupation of engineering ethics with specific moral dilemmas confronting individuals"* in American engineering ethics education. Zandvoort [6] reports that engineering ethics textbooks are inadequate in preparing students for what he calls the *"necessary knowledge for social responsibility"*. Perhaps in this context it is hardly surprising to learn that US engineering graduates are *"more likely than any other major to graduate believing that the chief benefit of college is to increase their earnings potential, that individuals cannot change society, and that it is not important to develop a meaningful philosophy of life* [7]*"*. This scenario appears even more dispiriting when it is compared with a UK study [8] which found that *"to make a difference to the world"* was the number two aspiration among first year engineering students prior to entering university (including the number one among females).

Professional Bodies – Accreditation requirements and codes of ethics

Professional bodies' codes of ethics tend to take a broadly similar approach to each other. The Engineers Ireland Code of Ethics [9] is typical with sections on 1) Relations with colleagues, clients, employers and society in general, 2) Environmental and social obligations and 3) Maintenance and development of professional conduct and standards. This code also contains a fourth section on enforcement procedures and disciplinary action. There are therefore sections on both micro (personal conduct, organisational) and macro (public, societal) ethical issues. However, in terms of the macroethical issues codes tend to vary considerably in terms of their requirements. For example, in the sustainability domain, Engineers Ireland requires that professionals shall, among (four) other statement requirements, *"promote the principles and practices of sustainable development and the needs of present and future generations"*, while the American NSPE requires that *"engineers are encouraged to adhere to the principles of sustainable development*[1] *in order to protect the environment for future generations.* [10]" Engineers Australia adopted a new code of ethics in July 2010 [11]. In draft form, one of its four pillars requires professionals to "promote sustainability", that is, to *"engage responsibly with the community and other stakeholders"* to *"practise engineering to foster the health, safety and wellbeing of the community and the environment"* and to *"balance the needs of the present with the needs of future generations."* By comparison other organisations' codes of ethics take a less expansive view. IEEE for example [12], cite ten tenets, mainly dealing with personal conduct (e.g. display honesty, reject bribery). They also require engineers *"to accept responsibility in making decisions consistent with the safety, health and welfare of the public, and to disclose promptly factors that might endanger the public or the environment"* Similarly, AIChE [13] simply require that its members *"hold paramount the safety, health and welfare of the public and protect the environment in performance of their professional duties."*

The codes of course reflect *"the values and beliefs of both professional engineering bodies and individual engineers"* [3] and are thus themselves present an evolving (micro and macro ethical) construct. They have come in for criticism for their microethical bias towards the individual agent at the expense of bigger picture societal responsibilities [2,14,15]. Perhaps the proposal by the UK's Accreditation body, the Engineering Council in its 2009 "Guidance on Sustainability" publication [16] for engineers to *"do more than just comply with legislation and codes"* is both an admission of the shortcomings inherent in many codes and part of a larger trend towards a broader self conception by engineers and their professional bodies("post engineering"). [17]

Towards a broader conception of engineering roles, responsibilities, values and ethics

If one recognizes the complex nature of the problems and issues engineers face and the world they inhabit (and all that this entails, including multiple levels of organisation, emergence, bifurcation, multi-agent and normative behaviour, inherent subjectivity, non linearity, holism and post modernism), then this demands a professional ethical construct which by extension incorporates a macroethical framework dealing with broader societal issues [18,19]. This requires getting away from the traditional ethical framework founded on moral philosophy, which is inherent in our teaching and outlook [2] and which is *"strongly influenced by the modernist ideal of getting it exactly right"* [18].

[1] NPSE defines sustainable development as *"the challenge of meeting human needs for natural resources, industrial products, energy, food, transportation, shelter, and effective waste management while conserving and protecting environmental quality and the natural resource base essential for future development."*

Such a framework must also recognize that engineering inherently requires multidisciplinarity in addition to participants own "object world" view, in particular good engineering requires perspectives from non engineering disciplines including the liberal arts [1,2,20,22]. Moreover, making explicit the context (e.g. organisational, social, legal, political) in which engineers work is important if they are to engage with *"collective or 'macro-ethical' issues"* [14]

The micro/macro ethical framework is well developed through the literature [2,14,15,19,21] though a few variations exist. Allenby [19] conceives of three levels; individual, social (at the organizational level) and macroethic (societal) while Conlon has proposed a model based on a sociological perspective [23] enveloping four quadrants: macro-objective (focus on social, economic and political structures and public policy), macro-subjective (focus on goals and values of the profession), micro-objective (focus on organizational culture and processes and the ability of engineers to prevent the normalization of deviance) and micro-subjective (focus on consciousness of individual engineers: their ability to identify and solve ethical dilemmas and their ethical will power)[2]. While the models present a useful framework for discussing practice, the respective divisions are in many respects nominal as some issues have both micro and macro features e.g. product safety (which is influenced by individual practice and organisational ethos (micro) but also by legislation(macro)) [3].

Sustainability as a vehicle for a broader role

Sustainability provides an obvious macroethical dimension to engineering ethics [3,19,24,25,26,27,28,29,30,31]. It is also emerging as a key manifestation in codes of ethics (see above) which is in itself a reflection of its increasing role in societal discourse. Recognition that engineers have an ethical duty towards sustainability implies a responsibility towards future generations. This requires an enhanced level of commitment to the environment and society as it disallows practice which may result in future negative consequences by virtue of passive neglect [15]:

> *"There are two ways to kill any living thing. One is to do something that causes acute harm; the other is to remove or destroy the supporting environment and allow the living thing to perish. Similarly, engineers can destroy or alter environments that support the global ecosystem and in such manner kill future humans on a global scale. Clearly, the moral responsibilities of engineers must include commitments for providing a high quality and sustainable environment for future generations."*

This in turn raises the question of a requirement to embed the precautionary principle into (ethically) good engineering practice ahead of short termism [21], particularly when dealing with complex ecological and societal systems. Ultimately, it may be that macro-ethical issues such as sustainability will become the norm for engineering practice [17] and in time we will (have to) arrive at a point where engineering practice will *"incorporate tenets of sustainability into all phases of …practice, so that 'sustainable engineering' eventually equates with 'good engineering.'"*[32]

Moroever, while ethics and sustainability certainly overlap it has been pointed out that they do not coincide [33];*"incorporating them in the same engineering course can be effective, provided that points of linkage are clearly recognized in the syllabus, a suitable combination of theory and practical applications is drawn upon and adequate teaching methods, including decision-making case problems, are used."*

[2] Furthermore, Conlon suggests that perhaps there are really just two levels because most of the dilemmas used in the individual approach always involve an organisational context and organisation. Moroever, while such models may be useful, Conlon suggests *"the real issue is whether the totality of the environment in which engineers work constrains or enables social responsibility and this involves looking at the integration of the different levels. It also involves having substantial theories about the kinds of economic and political arrangements which promote sustainability"*. (personal communication)

Teaching ethics – context

The formal teaching of ethics is an important part of the BE degree in Process and Chemical Engineering at University College Cork. This is also a requirement for accreditation and coverage of professional ethics is incorporated into a first year introductory module: 'PE1003 Introduction to Process & Chemical Engineering' [34], details of which are outlined in Fig 1.

Module Code/Title: PE1003 Introduction to Process & Chemical Engineering
ECTS Credit Weighting: 5
Module Co-ordinator: Dr Edmond Byrne, Department of Process and Chemical Engineering.
Module Objective: To understand the role and responsibilities of chemical process engineers and to apply strategies based on technical, ethical, sustainable, societal, safety and environmental grounds to the design and operation of industrial processes using systems based process engineering analysis.
Module Content: The role and responsibilities of the chemical engineer; dimensions, units and conversions; introduction to computing; unit operations; process variables; introduction to process control, material and energy balances, structure and technical analysis of process diagrams; professional engineering ethics, including the engineers role with respect to society, the environment, sustainability and health and safety, cost engineering.
Learning Outcomes: On successful completion of this module, students should be able to:
· Apply strategies of process engineering analysis and problem solving (specifically in relation to units and measurement, unit operations, basic process control, material & energy balances, process flow diagrams, cost engineering) to design basic industrial processes.
· Expound the importance of safety, the environment and professional ethics in chemical process engineering and in the broader world.
· Advocate the roles and social responsibilities of engineers within society.
· Research information on an engineering topic, and construct a case to defend one's position on technical grounds.
· Compile a brief report using relevant computer software and make a technical presentation to peers.

Fig. 1. Module description for PE1003 Introduction to Process & Chemical Engineering (2009/10)

The author of this paper has lectured this module since its inception in 2001 and during that time has applied a number of approaches to the topic of professional ethics. Earlier approaches had involved the use of popular case studies such as the case of the Challenger disaster [35], as developed for US engineering programs where the emphasis is typically on the individual agent, whistleblowing and other microethical considerations. I always found this unsatisfactory both from a student engagement perspective and from a personal perspective – the consequences seemed stark and immediate and the examples seemed both remote and unlikely to the students. I subsequently adopted a classroom case study applicable to chemical engineering students [36], modifying it (by localising the scenario to describe a Cork based biopharmaceutical facility) to provide something which was more immediate, likely and relevant, and didn't result in several unfortunate deaths. Nevertheless, the options which students were asked to consider were still confined to microethical issues where the individual agent was forced to consider between conflicting options, with the aim of identifying some best case (typically win-win) scenario.

Influenced by the work of Beder, Ravetz, Bucciarelli and Conlon [2,3,25,31,37] among others, and consolidated by high level initiatives by professional bodies such as the IChemE's Roadmap for 21st Century chemical engineering [38] ("*What does society need; what are the desirable outcomes and how can chemical engineers work in partnership with others to make it happen?*") and the 2007 Engineers Australia Sustainability Charter [39] ("*sustainable development should be at the heart of mainstream policy and administration in all areas of human endeavour*") I felt that the emphasis should be extended to incorporate macroethical issues.

A sustainability informed ethics based case study – water for Dublin

In 2009/2010 a case study was selected which sought to encourage students to consider macroethical issues in professional practice. The case study was based on the real life situation of converging water supply and demand in the greater Dublin area. Cogniscent of Dublin's population growth (from 1.5 million in 2010 to a projected 2.2 million by 2031), Dublin City Council have since 1996 [40] been looking at the issue, almost exclusively from a supply side perspective. This resulted in the commissioning of a study by Dublin City Council of engineering and water consultancy experts RPS and Veolia from 2005 to consider supply source options identified since 2000 [40]. This resulted in a report which suggested that (initially) water supply would match demand by about 2016 (revised in later versions to 2020-2022 [41]) thus providing ten options which were identified and analysed.

After public and state consultation, this resulted in the announcement in July 2010 of the selection of a scheme which involves building a pipeline to take water from the River Shannon at the upper reaches of Lough Derg in the Irish midlands, and pumping it to a newly created reservoir in an existing cutaway bog, roughly halfway between the river and Dublin, which it is proposed would also act as a 'water based eco park', before pumping the water on to Dublin. The reservoir would act as a buffer, being filled from Lough Derg during high flows when the river is in flood for storage while being depleted during dry periods. This project which it was reported *"would require about 2.5 per cent of the river's water"* [42] would cost €470m to build and €8m per annum to operate (2020 figures). However, there is no consideration of what should happen from around mid-century when supply and demand would again converge (according to the figures presented which suggest demand will increase linearly over time). Depending on whether the minimum (2056) or maximum (2047) 'planning scenarios' (water demand) are applied, the same problem would arise again in just another generation. For this and other reasons there is strong local opposition to taking water from the Shannon, the longest river in the British Isles, to sate Dublin's ever growing thirst [43,44]. Indeed the Shannon Protection Alliance (SPA) have published a report from environmental consultants which challenges many of the approaches taken by the original RPS-Veolia report [40]. This report claimed that RPS pointed out at a consultation meeting hosted by them in 2008 that *"whatever option is finally selected must be sustainable, i.e., the environmental, economic and social aspects must be properly balanced"*. Moreover, the SPA report also suggests that in the RPS-Veolia report:

> *"no attempt is made to quantify any possible or potential reduction in per capita consumption, while measures which have been regarded as normal in many other countries for at least 20 years, e.g., metering for private supply[3], use of rain water for sanitary purposes/toilet flushing/garden irrigation, and on site re-use of grey water, are not even mentioned, let alone considered.*
>
> *The predictions for population growth and per capita consumption are unchanged from those given in the Draft Feasibility Study published in May 2006. Per capita consumption is forecast to remain at 145 litres per head per day, giving rise to a total domestic demand of 317 million litres per day."*

Thus this issue was chosen as a basis for a class assignment. The title of the report reflected that taken by the RPS-Veolia project ('water supply'), but the outline text clearly describes the problem of water as being one of supply and demand. Students were given the assignment as part of the ethics section of the module which had been covered (both micro and macro ethics) in the previous few lectures. In these lectures an explicit link was made between sustainability and the ethical responsibility of engineering professionals and the Engineers Ireland Code of Ethics was provided and discussed. The meaning of a wicked problem was also outlined (e.g. [45], [46]) as were some of the basic tenets of sustainability science. The assignment (worth 10% of the module marks) is provided in Fig. 2.

Students were asked to critique the RPS-Veolia report, come up with their own proposed recommendations on resolving the problem, while considering how this coincides with their ethical responsibilities. This would be done as part of a group effort, and students would have some time to consider the report, the bigger issues involved, deliberate among themselves and then put together a group presentation. The presentation would be delivered to peers during a class session, and each group would be asked to critique and question one other group's presentation over a question and answer session for up to ten minutes. Students would be graded on their expressed levels of understanding of the issues involved as demonstrated by the team presentation as well as both their questions and answers.

[3] Water is still not charged for domestic consumers across all of Ireland (north and south) despite EU law. Neither is metering a feature of domestic supplies.

Assignment; A wicked problem; Water supply to Dublin for the 21st Century

Problem statement

The population of the Dublin region in terms of water supply is currently 1.5 million. The current average daily water requirement is 550 million litres. This equates to an average of 134 m^3 per person per annum. Water is supplied from water treatment plants operated by Dublin City Council and Fingal County Council supplied by water from the rivers Liffey, Dodder and Vartry. There are also a number of small groundwater sources in north Fingal (Bog of the Ring) and in Co. Kildare. The population is expected to increase to 2.2 million by 2031 however, and assuming per capita consumption remains constant, the predicted rate of growth the city's water demand would surpass capacity of existing supply from around 2016.

The principal contributing factors to water demand are 1) Population, 2) per capita usage and 3) leakage and wastage. Supply is also likely to come under pressure into the future. It has been predicted that water levels in the River Liffey (currently Dublin's principal source of water) could be just half of what they are today by mid century[4], and the changing climate *'will also have major implications for water resource management ..especially in the relatively crowded east, and the problems could be acute in Dublin and Belfast and other eastern towns and cities, for the areas of greatest demand are going to receive the lowest rainfall. ..Only Dublin's closeness to the Wicklow mountains and Belfast's proximity to the Mourne's,both of which receive copious amounts of rainfall, have prevented the issue from coming to the fore until now[5]'.*

This emerging issue was identified in a government publication on the Greater Dublin Water Supply Strategic Study 1996-2016. Following this, the engineering consultancy group RPS were commissioned to examine the issues and make suitable recommendations. Their reported findings were published in 2008 with an accompanying website (http://www.watersupplyproject-dublinregion.ie/). Possible options identified include increasing capacity by taking water from various points in the River Shannon, from the River Barrow, desalination of sea water and sourcing groundwater.

Task

You are a graduate engineer working with a consultancy company. Your company has been asked by the Irish Government through the Department of the Environment to review the RPS report and recommendations and having done this to recommend a preferred way forward. You and your small team have been asked by your employer to work on this project and prepare a report. The report should contain;

- A critique of the RPS report
- A proposed way forward along with suitable recommendations.
- You will need to provide a suitable rationale for your proposed option/s.
- As a team of engineering professionals, you should also demonstrate how and where, your proposals epitomise the Professional Code of Ethics.

You should research and reference as required and feel free to be innovative!

Presentation *[60 marks]*

Each group will be required to make a 10 minute presentation addressing the above topics. The presentation should be emailed to the lecturer (e.byrne@ucc.ie) before the presentation by the first named team member (below). During the presentation session each group will also be assigned another group whose work they will critique.

Critique *[Asking Questions: 20 marks; Answering Questions 20 marks]*

At the close of the presentation session, each group will consult and critique their designated group's presentation over a 15 minute period. A second session will then involve each of the presentation groups being interviewed by their designated examining group. Each member of the examining group should put at least a one point to the presentation group. Points may include general comments, discussion points, questions, follow-up questions, criticisms or praiseworthy comments, seeking points of clarification, etc. Each group will be questioned for a period of about 7-10 minutes and other class members will also have an opportunity to raise points.

Fig. 2. PE1003 Engineering ethics based assignment (2009/10)

Neither the SPA report nor any other material was presented nor cited in proposing the project so as not to direct the debate in any particular way; the aim was for them to research the issues themselves, reflect on them, develop their own conceptions, arrive a team consensus view (if possible) through deliberation and discussion with colleagues, and then present and defend their proposals among peers.

[4] According to studies by Dr John Sweeney of the Irish Climate and Research Unit at NUI Maynooth (http://www.rte.ie/news/2007/0822/water.html)

[5] Hickey, K., 2008, Five minutes to midnight? Ireland and Climate Change, White Row, Belfast.

Assignment Aims and Background

The overaching idea was to provide students with the opportunity to consider broader ethical considerations of professional practice as engineers, including macroethical issues. Such issues would in particular relate to sustainability and participants conception of it, which will likely vary and thus be challenged; for example in this case, sustainability has been invoked by a number of parties; the RPS-Veolia report suggests that the *"sustainable availability of 350Mld"* is required from a new source and that *"following consideration of feedback from the public consultation process, the water supply options were ranked in accordance with long-term sustainability criteria (Environmental, Economic and Social)."* [47]. Similarly, in the parallel public discourse surrounding this issue, supporters of the Shannon scheme have suggested that the current situation with respect to Dublin's water supply-demand situation is unsustainable while others have claimed that those objecting to the proposed Shannon scheme have an 'unsustainable' argument.

On the other hand, opponents to the proposed Shannon scheme have also used sustainability as a basis for their objections. For example, the Shannon Protection Agency report [43] states the following:

> *"The question of sustainability must also be examined in the wider context of a growing international awareness of how much water we consume, and the increasing concern about water shortages and conflicts between States and regions over access to ever-decreasing water resources. Closely connected with this issue is the accumulating evidence that abstracting significant volumes of water from river systems and lakes in various parts of the world has caused, and is continuing to cause, widespread ecological, social and economic losses and damage ..A report prepared for the World Economic Forum meeting held in Davos, Switzerland, earlier this year, stated the global concern succinctly:*
>
> *"There is a structural problem in how we manage water across the web of our global economy. Worsening water security will soon tear into various parts of the global economic system. It will start to emerge as a headline geopolitical issue. The volatility in food prices in 2008 should be treated as an early warning sign of what is to come. In many places around the world, we have consistently under-priced water, wasting and overusing it as a result. We have depleted stocks of groundwater at the expense of our future water needs. In effect, we have enjoyed a series of regional water "bubbles" to support economic growth over the past 50 years or so, especially in agriculture. We are now on the verge of water bankruptcy in many places with no way of paying the debt back. In fact, a number of these regional water bubbles are now bursting in parts of China, the Middle East, the south-western US and India; more will follow. The consequences for regional economic and political stability will be serious.[6]"*

Students' presentations

The twenty six students taking PE1003 were divided into six groups of four or five (determined alphabetically) for the purposes of considering the assignment and making the presentation. In general, through their presentations, the students stayed within the confined of the RPS report, and the recommendations of all the groups were ultimately taken from the options suggested in this report. Demand issues were only mentioned in a cursory fashion, if at all. Questioning by peers also reflected this and it was clear that students did not envisage their role as engineers (or as participants in this assignment) as having much to do with anything more that being 'paid hands' in finding the 'best' supply water option once guided along this path. Perhaps the initial spec was not clear enough (although I was keen not to try to unduly influence students responses, I did ask that they be creative and innovative in their consideration of the problem when discussing the problem with them.

[6] World Economic Forum (2009) Water Initiative: Managing Our Future Water Needs for Agriculture, Industry, Human Health and the Environment. Davos: January 2009.

By means of example, one group appeared first in their presentation to rule out water abstraction from the Shannon on the basis that *"taking water from the River Shannon on such a large scale is only a temporary solution to the problem, as we are all aware of the global decrease in freshwater levels"*, and that *"many locations situated on or near the banks of the river Shannon depend heavily on the river for water. ..It is both unfair and unethical to take this water."* They also went on to suggest that *"In doing this project we asked ourselves what is the role of an engineer? Is it to carry out the task we are required to do or is it more than this? To be innovative and futuristic or to offer solutions already known? We believe it is a broader role."* Their proposed actions ? They advocated desalination of Irish sea water with abstraction from the Shannon as a back up, making no mention of demand issues.

Other groups merely chose one of the options, including one group which came up with an elaborate scoring system which allocated points to each option based on aggregate marks for a number of relevant criteria, thus making the implicit assumption that the whole equals the sum of the parts. Each if the groups did relate the material to the professional codes of ethics, demonstrating how their proposals complied with the codes of ethics, though given the narrow interpretation of the task, their attempts could hardly be described as *"doing more than just complying with the codes"* [16].

Perhaps the principal reason that my expectations for this exercise were not fully realised was due to poor explanation on my behalf (Fig 2). Nevertheless, I would have hoped for a broader exploration and demonstration of an understanding of the issues involved, the inherent complexities and context of the problem at hand with a correspondingly better informed level of subsequent debate and discussion among the students. To try to address this, I envisage providing a clearer description of the requirements for future iterations (requesting that they read into all the broader issues involved).

Student engagement and relevance

To try to determine how students perceived the ethics section of the module, both in terms of enjoyment and perceived value, I asked students to fill in a questionnaire following the conclusion of the module.

Consider the following PE1003 topics in terms of how much you enjoyed them;

	Extremely enjoyable	Very Enj.	Somewhat Enjoyable	Not very enjoyable	Detested it
The role and responsibilities of the chemical engineer	3	12	7	2	
Dimensions, units and conversions		4	10	9	1
Introduction to computing		7	11	6	
Unit operations	1	8	14	2	
Introduction to process control	4	8	11		
Material and energy balances	3	8	12	2	
Structure and technical analysis of a process flow diagram; process variables	6	9	8	2	
Professional engineering ethics, including the engineers role with respect to society, the environment, sustainability and health and safety	5	10	7	3	
Cost engineering	4	3	11	6	1

Consider the following PE1003 topics in terms of how useful you envisage you will find them through your professional life;

	Extremely useful	Very useful	Somewhat useful	Not very useful	Don't see any point
The role and responsibilities of the chemical engineer	6	8	9	2	
Dimensions, units and conversions	4	18	3		
Introduction to computing	1	12	4	1	
Unit operations	9	10	3		
Introduction to process control	10	12	2		
Material and energy balances	14	9	2		
Structure and technical analysis of a process flow diagram; process variables	18	5	2		
Professional engineering ethics, including the engineers role with respect to society, the environment, sustainability and health and safety	8	8	8		
Cost engineering	10	9	5	1	

Fig. 3. Survey of students taking PE1003 Introduction to Process & Chemical Engineering 2009/10

The first question was designed to ascertain the level of stimulation and enjoyment the ethics section of the module (lectures and assignment) provided for students, particularly in relation to other sections of the module. The second question was to ascertain the perceived relevance of professional ethics to these first year students; this was the first process/chemical engineering module they'd encountered as part of their programme, along with other modules in maths, applied maths, physics, chemistry, etc. Students were asked to rate their enjoyment and perceived usefulness of all the topics on the module on a five point scale. The results of the survey are presented in Fig 3. 25 of the 26 students taking the module filled in the survey, and where the responses do not add up to 25 this is because the question was left blank.

It was encouraging that students ranked the professional engineering ethics section, which provided explicit material on the engineers role with respect to society, the environment, sustainability and health and safety, as the second most enjoyable topic covered out of nine (behind surprisingly 'structure and technical analysis of a process flow diagram/process variables'). Its perceived usefulness was comparatively lower at sixth out of nine, though even here, over two thirds of students felt that it was either extremely useful or very useful, with nobody feeling that it was not very useful. The associated 'role and responsibilities of the chemical engineer', which is the very first item covered in the module also scored highly on both counts with only a slightly less positive profile. These results are very encouraging, both in terms of the level of engagement and enthusiasm shown by the students in response to the approach taken, and in terms of convincing them of the level of importance of professional ethics. While I haven't provided this survey to students before when using case studies which considered only microethical issues, my guess (in line with the reported findings [4]) is that this approach would not lead students to the same conclusions in terms of the usefulness of professional engineering ethics through their professional life.

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