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TEACHING ENGINEERING ETHICS WITH SUSTAINABILITY AS CONTEXT

Abstract

Purpose– This research was carried out to ascertain the engagement and response of students to the teaching of engineering ethics incorporating a macro ethical framework whereby sustainability is viewed as context to professional practice. This involves incorporating a broader conception of engineering than is typically applied in conventional teaching of engineering ethics.

Design/methodology/approach– A real life wicked problem case study assignment was developed. Students' understanding and practical application of the concepts were considered. A survey was conducted to gauge students' appreciation of the professional importance and their enjoyment of the subject matter.

Findings– Students appreciate and enjoy a macro ethical sustainability informed approach, but find it more challenging to apply in practice.

Practical implications- This research demonstrates an approach to the teaching of engineering ethics using a practical example, which can help broaden engineers' self-perceived role towards one where sustainability is context. It also shows how students can find such an approach to teaching ethics to be both enjoyable and relevant.

Social implications– Engineers educated to perceive the importance of engaging with macro ethical issues as part of professional practice will be significantly better placed to inform public and industry policy towards greater good and engage with other professional and expert groups.

Originality/value– An approach to engineering ethics which diverges from the traditional is proposed. This can be of value to those involved in the teaching of engineering ethics, particularly those seeking to incorporate sustainability and other macro ethical issues.

Keywords - Ethics, Macro ethical, Sustainability, Water, Complexity

Paper type - Research paper

1. Teaching engineering ethics – current practice

Most professional engineering codes 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.

The typical means of teaching engineering ethics in professional programmes reflects the values and perceptions of both engineers and engineering educators. Engineering is typically regarded as somehow a 'value free' profession (Bucciarelli, 2010) which seeks to establish 'objective' criteria in making decisions and solving problems, including ethical ones. In this context, ethics is taught through the individualistic object world of the engineering profession (Bucciarelli, 2008) where the broader context is ignored (Conlon and Zandvoort, 2010). The teaching of ethics therefore reflects this though case studies which focus on micro ethical 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"* (Herkert, 2000) which are considered to result in 'correct' or 'optimal' outcomes. Context, complexity and a transdisciplinary approach tend to lose out to objective reality in such scenarios. 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 (Conlon and Zandvoort, 2010). 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. Such considerations are considered to be without the remit of the engineer. Nevertheless, the UK Teaching of Engineering Ethics Group (RAE/EPC, 2004) has 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"*

However, the traditional narrow view persists. Herkert (2000) has pointed to *"the traditional preoccupation of engineering ethics with specific moral dilemmas confronting individuals"* in American engineering ethics education. Zandvoort (2007) 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"* (Asrin, 1993). This approach contrasts with the idealistic outlook and intrinsic values that *incoming* students invariably hold: a UK study (Alpay *et al.*, 2008) found that *"to make a difference to the world"* was the number two aspiration among all first year engineering students prior to entering university, and the number one among females. Perhaps this holds a clue to the ongoing falling popularity of the engineering profession as a career across the developed world.

2. 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 (Engineers Ireland, 2009) 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 macro ethical 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 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[i] in order to protect the environment for future generations"* (NSPE, 2007). Engineers Australia adopted a new code of ethics in 2010 (Engineers Australia, 2010) whereby 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 (IEEE, 2006), 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 (2003) 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."*

Clearly the codes reflect *"the values and beliefs of both professional engineering bodies and individual engineers"* (Conlon and Zandvoort, 2010) and are thus themselves present an evolving (micro and macro ethical) construct. They have come in for criticism for their micro ethical bias towards the individual agent at the expense of bigger picture societal responsibilities (Vesilind, 2002; Bucciarelli, 2008; Zandvoort, 2008). Perhaps the proposal by the UK's Accreditation body, the Engineering Council (2009) in its 'Guidance on Sustainability' publication 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 (Mitcham, 2009).

3. 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 acknowledgement of multiple levels of organisation, emergence, resilience and fragility, bifurcation, multi-agent and normative behaviour, inherent subjectivity, provisional knowledge, non linearity and holism), then this demands a professional ethical construct which by extension incorporates a macro ethical framework dealing with broader societal issues (Allenby, 2006; Heylighen *et al.*, 2007). This requires getting away from the traditional ethical framework founded on moral philosophy, which is inherent in our teaching and outlook (Bucciarelli, 2008) and which is *"strongly influenced by the modernist ideal of getting it exactly right"* (Heylighen *et al.*, 2007). Such a framework must also recognize that engineering inherently requires transdisciplinarity in addition to participants own 'object world' view, in particular good engineering requires perspectives from non engineering disciplines including the liberal arts (Bucciarelli, 2008, 2009, 2010; Michelfelder, 2009). 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"* (Zandvoort, 2008).

The micro/macro ethical framework is well developed through the literature (Vesilind, 2002; Allenby 2006; Bucciarelli, 2008; Zandvoort, 2008; Conlon 2010) though a few variations exist. Essentially the micro focuses on the individual agent and on their ethical will power to 'act ethically' by identifying and solving ethical dilemmas at personal and organisational level through for example, whistleblowing. The macro level however focuses on the goals and values of the profession, accompanying socio-political and economic structures and the roles and responsibilities that the engineer and the profession can play in both realizing and deriving a meaningful relationship with these (Fig.1).

Allenby (2006) conceives of three levels; individual, social (at the organizational level) and macro ethic (societal) while Conlon has proposed a model based on a sociological perspective (Ritzer, 2001) 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 [ii]). While these 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)) (Conlon and Zandvoort, 2010). Of course, in reality there is no rigid or discrete boundary between micro and macro issues, and as befits a complex issue each level influences the other, while there can also be a degree of overlap in some instances. However, these models are merely useful constructs to help navigate ethical issues and do not in themselves bear any great importance beyond that (see [ii]).

4. Sustainability as a vehicle for a broader role

Sustainability provides an obvious macro ethical dimension to engineering ethics (Ladd, 1980; Herkert, 2001, 2005, 2006; Donnelly and Boyle, 2006; Ravetz, 2006; Allenby, 2006; Conlon, 2008; Colby and Sullivan, 2008; Conlon and Zandvoort, 2010). 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 social and ecological domains as it disallows practice which may result in future negative consequences by virtue of passive neglect (Vesilind, 2002):

> *"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 (Conlon, 2010), particularly when dealing with complex ecological and social systems. Ultimately, it may be that macro ethical issues such as sustainability will become the norm for engineering practice (Mitcham, 2009) 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'"* (Allenby *et al.*, 2009).

Moroever, while ethics and sustainability certainly overlap it has been pointed out that they do not coincide (El-Zein *et al.*, 2008);*"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."*

5. 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' (UCC, 2011), details of which are outlined in Fig. 2.

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 involved the use of popular case studies such as the case of the Challenger disaster (Mertzman and Madsen, 1993), as developed for US engineering programs where the emphasis is typically on the individual agent, whistleblowing and other micro ethical considerations. However this approach was invariably considered 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. A classroom case study applicable to chemical engineering students was subsequently adopted (Shallcross and Parkinson, 2006) and modified (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 micro ethical issues where the individual agent was forced to consider between conflicting options, with the aim of identifying some best case (typically win-win) scenario.

This approach conflicted with the work of Beder, Ravetz, Bucciarelli and Conlon (Beder, 1998; Ravetz, 2006; Bucciarelli, 2008; Conlon 2008; Conlon and Zandvoort, 2010) among others, while also failing to match the ethos underlying high level initiatives by professional bodies such as the IChemE's 'Roadmap for 21st Century chemical engineering' (IChemE, 2007) (*"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 (Engineers Australia, 2007) (*"sustainable development should be at the heart of mainstream policy and administration in all areas of human endeavour"*). It was felt therefore that the emphasis should be extended to incorporate macro ethical issues.

6. A sustainability informed ethics based case study – water for Dublin

During 2009/2010 and 2010/11 a case study was selected which sought to encourage students to consider macro ethical 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 been considering the issue (RPS-Veolia, 2008), 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 (RPS-Veolia, 2008). A resultant report suggested that water demand would begin to exceed supply from around 2016 (revised in later versions to 2020-2022 (RPS-Veolia, 2010)). These projections were based on an assumption of constant per capita consumption over time. Ten supply enhancing options were proposed and analysed.

After public and State consultation, an announcement was made in July 2010 favouring the selection of a scheme which involves building a 120 km plus pipeline to take water from the River Shannon at the upper reaches of Lough Derg in the Irish midlands, to be pumped to a newly created reservoir in an existing cutaway bog, roughly halfway between the river and Dublin, which it was 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"* (O'Halloran, 2010) would cost €470m to build and €8m per annum to operate (2020 figures). However, there was 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 (SPA, 2010; Sheridan, 2010). 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 (RPS-Veolia, 2008). 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[iii], 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."*

This wicked problem was thus chosen as a basis for a class assignment. Students were given an assignment entitled 'A wicked problem; Water for Dublin' as part of the ethics section (both micro and macro) of the module which had been covered through 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. Rittel and Webber, 1973; Ravetz, 1999) as were some of the basic tenets of sustainability science. The assignment (worth 10% of the module marks) is provided in Fig. 3.

As part of the assignment students were asked in designated groups to critique the RPS-Veolia report, come up with their own proposed recommendations on resolving the problem, while considering how this can be considered from an ethical perspective. 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 to encourage students to to consider the report, the bigger issues involved, to research the issues themselves (in relation to Dublin and other cities worldwide), reflect on them, formulate possible options, develop their own conceptions and innovative ideas, arrive a team consensus view (if possible) through deliberation and discussion with colleagues, and then put together a group presentation and defend their proposals among peers. As part of the presentations, each group was asked to critique and question one other group's presentation over a question and answer session for up to ten minutes. Students were graded on their expressed levels of understanding of the issues involved as demonstrated by the team presentation, on the innovation and coherence of the proposals put forward and by both their questions and answers.

7. 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 macro ethical 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)"* (RPS Engineering, 2010). 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 (SPA, 2010) states the following (quoting the World Economic Forum Water Initiative (2009)):

> *"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."*

8. Students' presentations

The students taking PE1003 in both 2009/10 and 2010/11 were divided into six groups of four or five (determined alphabetically) for the purposes of undertaking the assignment and the corresponding presentation. In general, despite having been exposed to a number of lectures on macro and micro ethics (as well as the framework presented here and relevant selected references) during which an explicit link was made between macro ethical considerations and sustainability, the students stayed within the confines framed by the RPS report through their presentations. For example, all groups accepted the presumption of constant per capita consumption over time and hence the need for a primarily ('engineering') supply based solution. Invariably, the 'solutions' that the students ultimately identified were adopted from one or more of the ten options outlined in the original RPS-Veolia report. Demand issues were only mentioned in a cursory fashion in most presentations, 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. This invariably meant that the options proposed focused on solutions which were chiefly technical in nature. Perhaps the initial assignment specifications were not clear enough. Although there was an effort not to try to unduly influence students' responses, they were asked to be creative and innovative in their consideration of the problem when the problem statement was being initially discussed. Students were also asked to *"research the broader issues involved"* (Fig. 3), though this did not appear to be taken up to any significant extent in terms of literature searches to ascertain how other global cities and communities have been dealing with the issue of water. Perhaps they could have been better primed and prepared to think outside the box of traditional engineering perceived wisdom and view the problem through a macro ethical sustainability lens through some brief in-class problems of a similar nature, followed by some class discussion.

By means of example with respect to the work presented, one group appeared in their presentation to first 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*." They then advocated desalination of Irish sea water though with abstraction from the Shannon as a back up, making no consideration of demand issues.

Other groups simply chose one of the options from the RPS-Veolia report, 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 in this case the whole is objectively quantifiable whereby it equals the sum of a number of discrete readily identifiable parts. Moreover, a number of groups did suggest some demand related issues such as provision of grants for water saving technologies (water collection, dual flush toilets, etc.) as well as public information campaigns, though these were in addition to supply measures such as increasing abstraction rates. Each of 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"* (EC, 2009).

Perhaps the principal reason that 'engineering' based solutions centered on technical supply based solutions were mooted was due to the priming of the assignment with an engineering consultants proposed solution. Students appear to perceive that if a solution is presented by a professional engineering consultant with a nice set of reports, graphics and an accompanying flash website, then the options presented must be the only viable credible ones. After all they might argue, the client would not be paying significant amounts of money if this were not the case. This however, may be part of the problem. How can engineers be expected to come up with anything other than a technical 'engineering' solution to wicked problems, if it is their interest to do so and thus make a case for infrastructural investment that engineering companies will in turn benefit from? This is particularly so if they are not aware of nor see the relevance of a macro ethical framework for professional practice. Solutions which incorporate 'soft' or non technical options may require less investment, infrastructure and consumption and may thus not fit so readily into the economic growth based development paradigm. Perhaps it is too much to expect that students would incorporate this broader perspective, even when covered explicitly through the preceding lectures, when they are then presented with a nicely packaged solution from a reputable engineering operation and asked to comment on it.

9. 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, they were asked to fill in a questionnaire following the conclusion of the module (Fig. 4). 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 degree programme. 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 4. 35 of the 36 students taking the module filled in the survey, and where the responses do not add up to 35 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 engineer's role with respect to society, the environment, sustainability and health and safety, as the most enjoyable topic covered out of nine (with about two thirds ranking this as either very or extremely enjoyable). It's perceived usefulness was comparatively lower relative to the others, 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. Another question was put to students during 2010/11 where they were asked whether they were more or less enthusiastic about the prospect of a career as a chemical engineer having completed this module and why. The results of this were encouraging. One student declared themself to be more enthusiastic because they *'realised the importance of* *imaginative, innovative solutions in the profession; realised that the job does not revolve solely on science'* while another suggested the reason for their increased enthusiasm to due to *'knowing now that I can help change and make the world a better place for people to live in'.* While this survey was not provided to previous students of the module, when case studies considering only micro ethical issues were employed, it might be assumed that, in line with the reported findings of Herkert (2000) and the author's own perceptions, that the traditional approach may not lead students to the same conclusions in terms of the usefulness of professional engineering ethics through their professional life.

10. Conclusions

This paper reflects on the teaching of engineering ethics to first year students incorporating a broadened maco ethical perspective, enabling sustainability issues to be considered on ethical grounds. The outcomes were very encouraging, both in terms of the level of engagement and enthusiasm shown by students in response to the approach taken. However, the practical application of this viewpoint is problematic for first year students who generally find the concepts of complex and wicked problems, inherent uncertainty and transdisciplinarity far more challenging than that of objective reality and the prospect of technical solutions through unique problem optimization. This is perhaps wholly understandable given their backgrounds and context, particularly as they were primed with an engineering report which proposes a technically based 'engineering solution' to a complex problem. Perhaps a more balanced approach whereby students are directed to material which looks at the water supply and demand issues in places where consideration of these issues have evolved (by necessity) to a greater extent, such as for example, in southwestern USA, would lead to greater student reflection, exploration and innovation. For example, Gleick (2010) proposes that while *"the waters of the west have been remade to serve humanity'*, and while *'these efforts brought important economic and social benefits",* the upshot of this is that *"the systems we have built are unsustainable without fundamental change".* In essence *"the engineering of water reservoir and transference systems as a comprehensive solution to Southwest water sustainability has run its course"* (MacDonald, 2010).

Therefore new approaches are needed incorporating a new (broader) conception of engineering, which recognizes macro ethical and hence sustainability perspectives as *"the 20th century approaches used to deal with water challenges are now failing, and new thinking and management approaches are needed."* (Gleick, 2010). Perhaps this points to the broader challenge which lies in convincing engineering practitioners that a simple 'engineering' approach is usually not the 'best' solution in a world confined by physical limits. The broader ethical framework applied here may serve as a signpost towards achieving such a change in paradigm.

Endnotes:

[i] NSPE 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."*

[ii] Furthermore, Conlon suggests that perhaps there are really just two levels because most of the dilemmas used in the individual approach always involve an organizational context and organisation. Moreover, while such models may be useful, Conlon suggests (through personal communication) that *"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".*

[iii] 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, although both are currently being proposed.

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Figures:

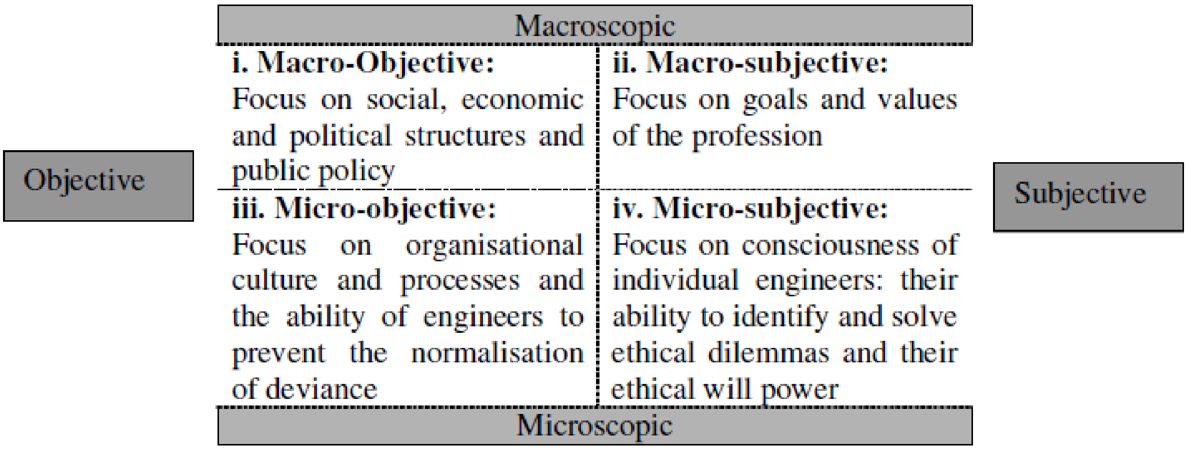

Fig. 1. Conlon's four quadrant model for engineering ethics (Conlon, 2010)

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. 2. Module description for PE1003 Introduction to Process & Chemical Engineering (2010/11)

Assignment; A wicked problem; Water for Dublin

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 m3 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, which if per capita consumption remains constant, would entail the city's water demand surpassing capacity of existing supply from around 2016.

Supply and Demand
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[1], 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.'*[2].

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/). They projected a constant per capita demand amid a rising population and thus explored means of boosting supply. Initial options identified increasing supply by increasing capacity by taking water from various points in the River Shannon, from the River Barrow, desalination of sea water and sourcing groundwater. Ultimately a pipeline supply from the upper reaches of Lough Derg via a midland storage facility was proposed.

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 which will match Dublin's water demand and supply. 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 means of **matching Dublin's water supply and demand** over the timescale involved along with suitable recommendations.
- 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 the broader issues involved and reference as required, including international trends and best practice, and feel free to be innovative!

Presentation
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.

Presentation [60 marks]

Critique
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.

Asking Questions [20 marks]
Answering Questions [20 marks]

[1] 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)
[2] Hickey, K., 2008, Five minutes to midnight? Ireland and Climate Change, White Row, Belfast.

Fig. 3. PE1003 Engineering ethics based assignment (2010/11)

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	6	17	10	2	
Dimensions, units and conversions	2	5	15	11	1
Introduction to computing	1	10	14	9	
Unit operations	4	12	17	2	
Introduction to process control	6	10	15	1	
Material and energy balances	3	15	15	2	
Structure and technical analysis of a process flow diagram; process variables	9	11	11	3	
Professional engineering ethics, including the engineers role with respect to society, the environment, sustainability and health and safety	10	13	8	4	
Cost engineering	4	8	12	10	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	11	11	11	2	
Dimensions, units and conversions	6	24	5		
Introduction to computing	5	15	6	2	
Unit operations	15	14	3		
Introduction to process control	14	17	2		
Material and energy balances	17	14	4		
Structure and technical analysis of a process flow diagram; process variables	25	8	2		
Professional engineering ethics, including the engineers role with respect to society, the environment, sustainability and health and safety	13	10	11		
Cost engineering	14	13	7	1	

Fig. 4. Survey of students taking PE1003 Introduction to Process & Chemical Engineering 2009/10 & 2010/11 (combined)