

Integrating Environmental & Social Considerations in the Curriculum of Undergraduate Electronic & Computer Engineering Students

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Abstract: This paper discusses the role that the Engineers Ireland accreditation process had in helping to embed two problem based learning (PBL) modules in the Department of Electronic & Computer Engineering at the University of Limerick which viewed together aim to give a rounded perspective on sustainability as it might apply to graduates in these disciplines.

The first of these is a second year module entitled “The Engineer as a Professional” dealing largely with engineering ethics and the evolution of codes of ethics, the role of the engineer in society and engineering responsibility. This module is examined using continuous assessment and is divided into ten problems or case studies that the students must solve in groups of three or four and make presentations to the class on the outcomes of their work. The assessment also requires the students to keep a reflective blog. Through problem solving the students are challenged to examine their own perceptions of an engineer’s role and the social impacts of engineering, while giving them a basic foundation in ethical theory and an overview of the competences of professional engineers as outlined by Engineers Ireland.

The second of the modules is a fourth year module entitled “Electronics & the Environment”. Again, this module is examined using continuous assessment, comprised of approximately ten problems, worked on in groups of three or four. The presentations and blog are also required. The problems cover topics on sustainable development, life cycle thinking, life cycle assessment, streamlined life cycle assessment, and other problems and design case studies in the electronics and information and communication technology (ICT) area.

Keywords; accreditation, problem based learning, engineering education, engineering ethics, technology and sustainability.

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1. THE CHANGING RESPONSIBILITIES OF ENGINEERS

The role afforded to engineers by society has changed dramatically in the last century. Almost 100 years ago, the 1912 Code of Principles of Professional Conduct of the American Institute of Electrical Engineers stated “The Engineer should consider the protection of a client’s or employer’s interests his first professional obligation and therefore should avoid every act contrary to this duty” (Harris et al., 2005). This is in stark contrast to the situation today where this obligation has been turned on its head. Engineers are now told that they should “place responsibility for the welfare, health and safety of the community at all times before responsibility to the profession, to sectional interests, or to other engineers” if they wish to be

considered for the title of Chartered Engineer (Engineers Ireland, 2005). When making a commitment to comply with the current Code of Ethics from Engineers Ireland, engineers are undertaking to “promote the principles and practices of sustainable development and the needs of present and future generations” and to “strive to ensure that engineering projects for which they are responsible will, as far as is practicable, have minimal adverse effects on the environment, on the health and safety of the public and on social and cultural structures” (Engineers Ireland, 2009). These statements, and others of similar sentiment, are now liberally spread throughout these touchstone documents. The language is very clear; sustainability is now considered to be a core concern for engineers and must be given due priority in the formative education of engineers.

2. THE ROLE OF ACCREDITATION IN EFFECTING CHANGE IN ENGINEERING COURSES

2.1 Accreditation

Engineers Ireland has as one of its purposes “setting up and maintaining proper standards of professional and general education and training for admission to membership or to any category of membership of the institution” (Engineers Ireland, 2007). Programmes which satisfy their criteria are deemed to meet the education standard required of individuals seeking one of the registered professional titles of Chartered Engineer, Associate Engineer and Engineering Technician. Moreover, under international agreements such as the Washington, Sydney and Dublin Accords, accreditation decisions of Engineers Ireland are accepted in signatory countries on the same basis as their “home” graduates. Engineers Ireland is also a member of the European Federation of National Engineering Associations (FEANI) and all engineering degree programmes that they accredit as satisfying the educational standard for Chartered Engineer are accepted in the member countries of FEANI.

This domestic and international recognition of the high education standard that a programme must achieve to receive such accreditation is rightly coveted by engineering departments in institutions throughout the country and those who have achieved accreditation in the past are loath to lose it. It is the view of the author that the accreditation process undertaken by Engineers Ireland every five years can become the primary lever in effecting change, or even transformation, to more sustainable paradigms in engineering education. From section 1 it is clear that the accreditation panels are mandated to adopt such an approach and if pursued constructively, yet aggressively, are best positioned to overcome inertia, conservatism or lethargy that may exist in engineering departments.

2.2 Experiences of Accreditation

The electronics course was one of the original courses at the National Institute for Higher Education (NIHE) Limerick, starting with a B.Tech in 1972 before moving to a BSc. in the late seventies and a B.Eng in the early eighties. The B.Eng. course first achieved Institute of Engineers Ireland (IEI) accreditation in 1985 and has maintained continuous accreditation ever since. The course is now designated as a B.E. In the report from the 2005 Engineers Ireland accreditation visit it recommended that

“Ethical, environmental and such matters should be strengthened within the core modules of the programme”.

In response to this the department developed a core module entitled “The Engineer as a Professional” dealing largely with engineering ethics and the evolution of codes of ethics, the role of the engineer in society and engineering responsibility. This module was included as core in the autumn semester of second year in the engineering programmes, replacing a choice of some general non-engineering elective modules. The department also introduced a module entitled “Electronics & the Environment” which was included as a specialist elective in the autumn semester of fourth year. This module covers topics on sustainable development, life cycle thinking, life cycle assessment, streamlined life cycle assessment, and other problems and design case studies in the electronics and ICT area. However, it was not given core status as agreement could not be reached on what module it would replace. The conversations at this time were fractious and arguments revolved around the issue of the relative importance of this topic vis à vis more traditional technical subjects. In the view of the author this sentiment reflects the emotional investment that many academics have made in their own particular specialist area and represents a significant barrier to change.

In the subsequent accreditation visit in December 2009 the report includes a section on features and strengths of the programme which states

“The Panel were impressed by the evidence for academic achievement on the programme in several areas. The core "Engineer as a Professional" module was felt by the Panel to be an excellent addition to the programme since the last accreditation panel visit, and its teamwork development activity in particular was felt to be a model of good practice that could be promulgated as such within the sector.

The Electronics & the Environment module was also noted as a very positive addition to the programme, although not contributing to the Programme Outcomes for every student on the programme because of its position as an elective module.”

The Electronics & the Environment module is now included as a core module in the Electronic Engineering degree. This is in spite of the fact that achieving European Credit Transfer and Accumulation System (ECTS) compliance involved a significant restructuring of the programme to achieve uniformity with the rest of the University of Limerick’s (UL) programmes.

3. PROBLEM BASED LEARNING

The traditional University teaching model in science and engineering is teacher centered and based on lecture, tutorial and laboratory sessions. This can encourage reliance on lecture/laboratory material for the answers necessary to complete coursework and pass exams but

does not necessarily encourage a deep and lasting understanding of the subject, nor help students to apply their knowledge in a practical situation. While this problem applies to all areas it is particularly worrisome in modules dealing with sustainability in engineering due to its role as a guiding myth as opposed to an objective set of design criteria (Allenby, 2007) so when inserting these new modules in to the program it seemed sensible to attempt to avoid these problems. In conjunction with this the PBL methodology fits very well with the millennial generation students expectations of personalisation and customisation of experiences. It can facilitate their desire to explore and experiment, to get involved, and test and, very importantly, to receive instant gratification (Ranky 2010). A set of carefully designed problems using the PBL methodology can be used to overcome these pitfalls and achieve the desired learning outcomes.

PBL is now used across the world in a wide range of disciplines. It is a shift from the teaching paradigm to the learning paradigm. The focus is on what students are learning rather than what the teacher is teaching. At the core of PBL curriculum design is a set of well-designed, ill-structured or open-ended, real-life, engaging problems. Research shows that compared to traditional lecture based instruction PBL, improves student understanding and retention of ideas, critical thinking, communication and problem-solving skills, as well as student's ability to adapt their learning to new situations. During the PBL sessions the instructor effectively acts as a consultant, guiding the students as they search for the appropriate resources and providing scaffolds for learning (Barrett et al., 2005).

Both "The Engineer as a Professional" and "Electronics & the Environment" are examined using continuous assessment and PBL. The modules are divided roughly into ten problems, each of one week in duration that the students must solve in groups of three or four. Each group has a chair, a scribe and a timekeeper and they are presented with the problem at the start of the first session of the week. The lecturer generally gives a 30 minute background lecture and engages in questions and answers with the students. During this session they must

- Name facts
- Clarify what they think the problem is
- Brainstorm ideas based on prior knowledge
- Identify what they do not know (learning issues)
- Specify an action plan and assign tasks

After this session they engage in independent study on the learning issues identified. When they return for the second session of the week they share information and resources, and peer-teach their proposed solution to the problem.

In the final session of the week a representative of each group makes a presentation to the class on their solution to the problem and the lecturer gives an overview of the topic and feedback on the presentations. The students also have an opportunity to ask questions and discuss the topic. After this they write-up an individual reflective blog on the problem and this is submitted the following week.

4. THE ENGINEER AS A PROFESSIONAL

The learning outcomes for “The Engineer as a Professional” are as follows

- The students will analyse and discuss the utilitarian and respect for persons ethical principles.
- The students will examine and discuss the relationship between common morality and professional codes of ethics
- The students will demonstrate an understanding of the role of reflective practice in continuous professional development
- The students will demonstrate an understanding of the role and responsibilities of professionals in society and the function of professional bodies.
- The student will analyse the importance of teamwork and the role of leadership in the completion of complex tasks.
- The students will demonstrate their capability of making a competent technical presentation to their peers.
- The students will demonstrate their ability to work in teams through practical activities.
- The students will demonstrate their written communication ability through a series of technical reviews and reflective logs.
- The students will demonstrate their ability to critically analyse their own learning requirements through a series of reflective logs.
- The students will demonstrate their ability to analyse problems from an ethical viewpoint and develop creative middle ways in cases of conflicting values.

Through the course of the semester the weekly projects seek to achieve one or more of these learning outcomes. Some of these projects involve undertaking a structured reflection, supported by recommended literature, based on an activity or exercise undertaken by the class. For example, the class spends a half day on teamwork exercises at the UL Activity Centre, shown in Figure 1, after which they must consider the role of teamwork in engineering and reflect on their performance in teams from individual, relational, contextual and development perspectives.



Figure 1 Engineering students participating in team activities at UL Activity Centre

Another exercise like this is to give the students a class session to examine the “Carter Racing Case Study” which is based loosely on the events leading up to the Challenger disaster in 1986. After making a decision on whether to race (launch) or not the students must reflect on their decision giving particular attention to the issue of responsibility in engineering with reference to professional bodies and codes of ethics. The story of Roger Boisjoly in the Challenger case makes for a particularly inspirational engineering role model (Harris et al., 2005).

The problems also take the form of case studies where students must delve into the relevant literature in order to piece together a coherent solution. An example of this is where they must use the line drawing methodology to make a decision on a course of action when given a case study that presents an ethical grey area. In order to do this of course they must first research the methodology, examine some previous case studies that have applied it and then set about applying it themselves. Examples of case studies would include situations where gifts/bribes or invasion of privacy are involved but not clear cut.

Another very effective problem which helps students to explore different ethical theories is to have groups prepare arguments for a debate on the use of human cadavers as automotive crash test dummies (“utilitarianism” says yes, “respect for persons” says no). After this debate they must then explore creative middle ways.

5. ELECTRONICS & THE ENVIRONMENT

The learning outcomes for “Electronics & the Environment” are as follows

- The students will analyse and discuss the inter-relationship of economic, social and environmental aspects of sustainable development
- The students will demonstrate an understanding of the importance of examining the whole life cycle when evaluating environmental impacts and evaluate the various methodologies for so doing.
- The students will examine and discuss the relative environmental impacts of different technologies and different methods of delivery of function.
- The students will examine and discuss the relative merits of different eco-labelling schemes.
- The students will create designs of sustainable technological systems.

Again, through the course of the semester the weekly projects seek to achieve one or more of these learning outcomes. The early weeks in the semester are used to establish basics such as what is sustainable development, life cycle impacts and life cycle assessment (LCA). The problems advance to interpreting reports such as Ericsson’s LCA study on a 3G system and suggesting improvements in system design based on the results. The problems progress to comparative LCAs between thin client and thick client computing or LED and fluorescent backlight monitors. The PBL methodology also enables classes on topical subjects and the release of Windows 7 presented the opportunity to examine whether this new operating system would be beneficial to the environment or not. Further problems explore PC eco labels and eco design, product service systems and the Waste Electrical & Electronic Equipment (WEEE), Restriction of Hazardous Substances (RoHS) & Energy Using Products (EuP) Directives. The

final capstone project requires the students to design a sustainable computing service as part of the Limerick Regeneration project.

6. CONCLUSION

This paper has described the experience of the Dept of Electronic & Computer Engineering at the University of Limerick in its attempts to include sustainability in the curriculum of its undergraduate degrees. Using the Engineers Ireland accreditation process as a catalyst for change it has introduced two new modules focussing on the ethical responsibilities of engineers towards society and the environment. Given the enormous scope of these issues and the pressure for space in the typical undergraduate engineering programme the PBL methodology has been found to be a very effective way of introducing the subjects and stimulating independent research by the students. It also satisfies the demands of millennial generation students for personalisation and customisation of experiences; to explore and experiment, to get involved and test and to receive instant gratification.

In the view of the author, the use of individual modules to address these areas should be seen as a stepping stone to introducing sustainability throughout the whole curriculum. However, the use of dedicated modules is vital to developing, in our students, a sound fundamental and theoretical understanding of sustainability upon which they can build on in their technical subjects and should not be bypassed. The application of theoretical principles to the analysis and solution of engineering problems is the essence of engineering practice and no less of a theoretical foundation should be afforded to the sustainability dimension of this practice. The inclusion of small aspects of sustainability into individual modules in the absence of a detailed introduction and overview runs the risk of simplifying the issue into “rules of thumb” or simple checklists which run counter to best educational practice. A deeper theoretical engagement gives students the tools to build their understanding of sustainability throughout their careers which is essential for lifelong learning and continuous professional development.

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