

Integrating ethics across the engineering curriculum through sustainability and legislative topics

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PROCEEDINGS



INTEGRATING ETHICS ACROSS THE ENGINEERING CURRICULUM THROUGH SUSTAINABILITY AND LEGISLATIVE TOPICS

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ABSTRACT

The paper explores the inclusion of sustainability and legislation related coverage in Engineering programmes in Ireland in the context of increasing calls for integrating ethics across the curriculum. It is part of a broader study examining engineering ethics education conducted in cooperation with the national accrediting body, Engineers Ireland. The study includes 23 Engineering programmes from 6 institutions in Ireland that underwent accreditation between 2017-2019. Mixed research methods have been employed, such as documentary analysis of module descriptors and of materials submitted for accreditation, as well as interviews with evaluators serving on accreditation panels and lecturers within the participant programmes. This led to the identification of two main themes employed to convey ethical content that are deemed to be suitable candidates for the integration of ethics across the curriculum, with coverage present in a wide variety of modules, such as technical modules, design modules, professional formation modules, final year projects, work placement, business and legal studies modules. We examine how each of these two main themes purporting to sustainability and legislation have been employed for the integration of ethics across the curriculum, by looking at the teaching and assessment methods employed. Our contribution thus aims to provide insights and examples that can guide programme chairs and lecturers in the implementation of ethics in varied module types across the curriculum.

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1 INTRODUCTION

Recent years witnessed a greater call for integrating ethics across the engineering curriculum, in modules with both a technical and non-technical orientation ([1]; [2]; [3]; [4]). There are several advantages mentioned in connection to teaching and assessing ethics in several modules throughout an engineering programme, such as providing a holistic and interdisciplinary approach that “mirrors the ways in which ethical issues arise in day-to-day engineering practice” ([1], p.545), thus allowing students “to see ethics in action” ([4], p. e114). The integration of ethics across the curriculum also helps students become aware of the intrinsic connection between ethical concerns and technical content, by rectifying the preconception that ethics is just an “add-on material” ([2], p.346). As such, this approach is considered to be more effective in improving engineering students’ moral reasoning and sensitivity to ethical issues than solely having dedicated modules on ethics ([3], p.223). Nevertheless, there are also significant challenges reported about the method of implementing ethics across the engineering curriculum. The most significant challenges relate to the background of engineering lecturers and their lack of familiarity with societal and ethical related topics [2], but also students’ reticent attitude towards ethics [5].

Our paper examines the integration of ethics across the curriculum in engineering programmes in Ireland through the prism of sustainability and legislation related coverage. These topic areas fall under one of the seven criteria listed by Engineers Ireland [6] that Engineering programmes have to demonstrate for accreditation. Programme outcome E dedicated to ethics requires graduates to show “knowledge and understanding of the social, environmental, ethical, economic, financial, institutional, sustainability and commercial considerations affecting the exercise of their engineering discipline”, as well as “knowledge ... of engineering practice, and the impact of engineering solutions in a societal and environmental context” and “commitment to the framework of relevant legal requirements governing engineering activities, including environmental.” Furthermore, it has been pointed out that a focus on sustainability and policy may provide a means for broadening engineering ethics education beyond a micro ethical approach ([7]; [8]; [9]; [10]; [11]).

We argue that sustainability and legislative related coverage can be good candidates for integrating ethics across the curriculum. The paper provides insights and examples that can serve as guidance to lecturers and programmes in light of an expressed need for guidance on how to implement ethics across the engineering curriculum ([10]; [12]).

2 METHODOLOGY

In order to determine the implementation of ethics in Engineering programmes in Ireland, three research methods have been employed: (a) document analysis of the documentation which was either prepared by the programmes for accreditation or is available online on the website of all 23 participant programmes; (b) participant observation at the accreditation events of 11 programmes offered by 3 institutions and (c) interviews with lecturers from the participant programmes teaching a professional

formation module and evaluators who served in the accreditation panel during the events observed. These methods are seen as complementing each other in order to develop a comprehensive insight into the implementation of ethics education in the participant programmes.

The scope of the study was limited to Engineering programmes that underwent accreditation between 2017-2019. Twenty three programmes offered by 6 institutions are included. Our analysis focuses on modules that the programmes themselves have deemed to have the highest contribution to meeting programme outcome E for accreditation. To identify these modules, we relied on a mandatory rubric in the documentation submitted by the programmes for accreditation, in which the programmes self-assess how they meet each of the seven programme outcomes. Thus, the modules that were assessed by the participant programmes with the highest contribution to outcome E were singled out for a documentary analysis of the topics and learning outcomes employed in connection to ethics instruction.

The documentary analysis relies on two main data sources: a rubric present in the documentation submitted by the participant programmes for accreditation, by which the programmes describe how they meet programme outcome E, and the module descriptors provided either as an annex to the documentation submitted for accreditation (6 programmes), part of the evidence presented during the accreditation events observed (11 programmes) or posted online on the programmes' website (6 programmes). At the end of this stage, there was a total of 83 unique modules with a strong contribution to meeting programme outcome E. The next research stage was dedicated to analysing the content input from the previous stage, following two iteration steps. First, a codebook was generated with 28 initial codes covering curricular content purporting to ethics informed by the standard description of topics falling under outcome E [6] and the literature about the content of engineering ethics education. Then a second iteration followed, which grouped the initial thematic codes under broader categories.

Having established the major themes employed to teach ethics in the participant programmes, we sought to get a more in-depth exploration of the topics and methods used to teach ethics. This was achieved through a series of interviews. Sixteen lecturers of professional formation modules were questioned about the topics and methods employed in teaching ethics. Six evaluators who served on the panels of Engineers Ireland during the accreditation events of 3 institutions observed by the researcher, were also interviewed. The evaluators were questioned about their views on engineering ethics education and its implementation in the evaluated programmes.

3 IMPLEMENTING ENGINEERING ETHICS EDUCATION ACROSS THE CURRICULUM: THE EVALUATORS' PERSPECTIVE

All six evaluators interviewed for the study showed a preference for seeing ethics integrated across the curriculum rather than in dedicated modules. This approach is considered to foster the development of holistic engineering graduates that do not

divorce ethics from the technical solutions they pursue. As one evaluator claims, “that is the way it has to go if we want to produce engineers that consider ethics as part of their direct reasoning.” Another evaluator argues that ethics “has to be across, we do not just want to see it in the professional development modules, you would like to see some mention of it elsewhere in the other modules as well. [...] You cannot just be ethical in one module, there should be an element of it everywhere.” This opinion is shared by a third evaluator who considers that “ethics possibly should be brought into more modules as opposed to just being covered in a module”. The reasoning behind this preference is that having ethics addressed in a dedicated module could contribute to the perception of the topic as an add-on, “just to get it in the course”, and thus minimizing its importance in the engineering curriculum.

Based on the interviews conducted, there is a sense that technical and ethical issues need to be “combined and fused in real life situations.” Nevertheless, evaluators consider that engineering programmes are not yet at the stage of implementing ethics across the curriculum. “It is not quite there yet. I do not see any programmes where it is permeating throughout”, states one evaluator, while another evaluator agrees that “most modules do not cover ethics. In any module that has a high technical content, probably ethics is not covered there.”

A challenging aspect according to one of the evaluators is that “for some modules it is going to be hard to bring it into light”. This point is expanded by another of the evaluators questioned. Accordingly, “it is very difficult because of the way the existing crop of academics were taught engineering was in a very different way to the way we are teaching engineering now”, which leads to a “slow process of getting people to think more holistically in their approach to engineering education”. There is an agreement among the evaluators for the need for more guidance on how to implement ethics more effectively, especially in the case of technical modules.

4 SUSTAINABILITY ACROSS THE CURRICULUM IN PRACTICE

When analyzing how ethics is being integrated in the curriculum of the participant engineering programmes from 6 HEIs in Ireland, we found that sustainability is the most popular theme employed in connection to meeting programme outcome E for accreditation. Table 1 shows that 49 (59%) modules deemed to have a high contribution to outcome E incorporate sustainability related topics. The topics mentioned in connection to the teaching and assessment of the theme of sustainability are the principles of sustainable development, environmental impact and protection, climate change, carbon management, energy efficiency, renewable energy, life cycle analysis, waste management, sustainable economic growth and eliminating poverty traps. We also note a higher emphasis on the environmental dimension of sustainability than on its social and economic dimension.

The theme of sustainability is covered in a wide variety of module types, such as technical modules, design modules, professional formation modules, capstone projects, work placement programmes, business studies modules as well as legal

studies modules². More so, as seen in Table 1, sustainability related coverage is present in more than half of the modules that have a strong contribution to outcome E from each module type. This suggests that sustainability might be a good candidate for integrating ethics across the curriculum

Table 1: Distribution of sustainability related coverage across module types (n=83 modules)

Technical modules (n=36)	Design modules (n=15)	Professional modules (n=12)	Capstone Projects (n=8)	Work Placement (n=2)	Business studies modules (n=6)	Legal studies modules (n=3)	TOTAL %
19	10	8	5	1	4	2	59%

From the perspective of lecturers, sustainability has the advantage of being a theme that suits the technical expertise of engineering faculty members. As one lecturer states, sustainability coverage has “the potential” to be integrated in technical modules. According to her, ethical questions about energy efficiency and waste production “did resonate because people could see how they might be involved in something that could be problematic”. Sustainability is also found to be appealing to students, who were found to show “a real interest.” Reflecting on the classroom experience, one lecturer noticed a real focus on the Sustainable Development Goals, with students commenting that “this was something they really enjoyed”.

These observations seem to address two common challenges highlighted by current research on engineering ethics instruction. One such challenge is the engineering faculty’ lack of familiarity with the topic, which hinders the linkage of ethical concerns with technical subject matters ([13]; [14]; [15]; [16]; [17]). A second challenge is the students’ negative reception and engagement with nontechnical content ([15]; [16]; [18]).

Sustainability is present in the curriculum of the participant programmes both in taught components and assessments. In what follows, we describe some of the evidence of sustainability coverage in both these components. Table 2 shows that the participating programmes incorporate sustainability topics through various taught components, such as lectures, case studies, community service, online polling systems and documentaries.

Some examples of topics introduced in lectures are the principles of sustainable development, environmental policies and standards, environmental and ecological theories representative of the Western, Buddhist and Native American traditions and the role of engineering in addressing wealth inequality. The topics included through lectures show a concern with both the environmental and socio economic dimension of sustainability.

² An exception, considered insignificant, is for the only module categorized as a personal development module in light of its focus on learning outcomes related to healthy lifestyle, time management a.s.o. This module does not offer coverage related to sustainability.

The case studies used by the lecturers interviewed aim to foster students' reflection on the implications of developing technologies that fail to meet environmental standards. For example, a case study about wastewater treatment using realtime data explores the "(un)certainly of knowing" that the discharge from the respective technology is "actually polluting the environment or was it just that we took one sample and that sample is inaccurate?" Students are exposed to the various type of ethical concerns that arise, such as "the rigor and integrity of their data collection and management, the cost benefit of different solutions, and the impact of one solution over another."

Community engagement has been mentioned in connection to designing "socially-conscious building retrofits that are student initiated and with clear relevance to societal contribution and community awareness". While an example of documentary shown in class addresses "what is progress from a critical perspective, looking at various aspects of sustainability and how they are interlinked." Online polling systems have been used by one lecturer to ask students to input the moral decisions they make in their daily lives for tackling climate change.

Table 2 Teaching methods incorporating sustainability issues

Type	Example of content
Lectures	Principles of sustainable development The relationship between a country's GDP and associated energy use Wealth inequality Local and/or international environmental policies and legislation Environmental ethics, inclusive of different traditions of thought
Case studies	Ethical dilemmas about sustainability aspects
Community service	Developing environmentally-friendly and/or socially-conscious solutions based on needs identified through direct interaction with a non-profit entity or a community group
Online polling systems	Exploring students views on different aspects of sustainability
Films and documentaries	Surviving Progress, The True Cost, A Plastic Ocean, A Cadillac Desert

We see that the integration of several various teaching approaches leads to a more holistic approach to the topic of sustainability, which incorporates its three pillars of environmental protection, economic viability and social equity. This seems to suggest that a hybrid approach to the incorporation of sustainability in the engineering curriculum is needed in order to offer students a more rounded understanding of the topic.

In order for the integration of ethics across the curriculum to be successful, it was argued that the inclusion of ethics in taught components is insufficient by itself if it is not accompanied by an assessment of the ethical components of technical modules ([19], p.1132). [20] agrees that the inclusion of ethical and social reflection in "even 10% of homework and exam questions", could reverse engineers' "slide into disengagement." In what follows, we present several examples of the integration of sustainability aspects in the assessment methods employed by the participant programmes. As seen in Table 3, sustainability was found to be included in exam question, research projects, design projects and capstone projects.

Table 3 Assessment methods incorporating sustainability issues

Type	Example
Exam questions	discussing the ethics of landfilling
Research projects (reports, posters and presentations)	about the sustainable development goals about the state of energy legislation in Ireland and the EU identifying stakeholder positions in national debates on adoption of wind energy or current ban on nuclear power
Lifecycle assessment analysis	Whether EV are an environmentally friendly solution
Design projects	Projects that incorporate the design for environment approach
Capstone projects	Mandatory rubric discussing the ethical implications and issues arising in the final year project

One of the lecturers interviewed gave the example of an exam question which asked students to discuss the ethics around landfilling, and “whether it is a problem or an opportunity, whether you can generate energy and actually recover things from it and turn it into a positive, or whether the negatives do outweigh that”.

Research projects are a popular method of incorporating sustainability topics in assessment. Some of the examples mentioned by lecturers revolve around presentation or written reports on the sustainable development goals. A lecturer described how the report assignment is asking students “to put the context of why the chosen goal was a challenge, and then to discuss what progress had been made so far and to critique whether that was sufficient progress, and then what environmental engineers could do in order to meet the 2030 target”. Another example of a research project asks students to analyse energy policies across a number of countries, with a focus on their impact on the adoption of bio-energy technologies “that could lead to sustainable, cyclic energy systems”.

The majority of capstone projects incorporate a mandatory rubric that requires students to include a section in their thesis where they reflect at the ethical implications and issues arising in their projects. This rubric is found to explicitly mention sustainability as one of the implications to be considered. For the programmes that do not yet have this requirement for the final year project, evaluators mentioned its absence and suggested the introduction of an ethics section.

5 Legislative coverage across the curriculum in practice

As seen in Table 4, legislative related coverage is another popular thematic area, present in 45 (54%) of the participant modules with a high contribution to outcome E. The topics mentioned in connection to the teaching and assessment of the legislative theme are national and international standards, directives, regulations, policies and legislation, CE marking, product liability, contract documents and planning requirements, intellectual property and patent law, as well as GDPR.

Table 4: Distribution of legislative related coverage across module types (n=83 modules)

Technical modules (n=36)	Design modules (n=15)	Professional formation modules (n=12)	Capstone Projects (n=8)	Work Placement (n=2)	Business studies modules (n=6)	Legal studies modules (n=3)	TOTAL %
13	10	8	5	2	4	3	54%

The inclusion of legislation related issues in engineering ethics education is seen as facilitating engineers to take a more active role in policymaking. As such, a lecturer singles out the medical profession, who “takes a role in advising the governments and in regulating, a much stronger role than the engineering profession has.” Given the “massive societal challenges ahead now with climate change”, one of the lecturers interviewed favours the inclusion of regulatory and legal issues in engineering ethics education to prepare “the engineering profession as a whole for stepping up to that. I guess that begins in education.” This viewpoint is shared by another lecturer, who agrees with the inclusion of regulatory and legal issues in ethics education, such as “environmental directives,” the “precautionary principle” and the “polluter pays principle,” in order to prepare students to address the problems raised by climate change. A lecturer militates for the inclusion of legislative issues, stating that “it needs to be integrated because a lot of the ethical questions are around the edges of legal questions,” while another considers that “when regulations, policies and the law are complex, and there are many grey areas, this is where ethics is very important”.

The theme is incorporated through taught components such as lectures, lab demonstrations and case studies, as seen in Table 5.

Table 5 Teaching methods incorporating legislative issues

Type	Example of content
Lectures	National and international standards, directives, regulations, policies and legislation. CE marking. Product liability. Contract documents and planning requirements. Intellectual property and patent law. GDPR
Lab demonstrations	Health, Safety and Welfare at Work Regulations, National Rules for Electrical Installations (ETCI Regulations), European directive on operating machinery
Case studies	Whistleblowing in the context of legal requirements and protection

Some of the frequent topics included in lectures revolve around standards such as ISO2600 on social responsibility, safety standards and quality assurance standards such as ISO9000. Intellectual property is another frequent thematic topic mentioned in lectures across all engineering disciplines. Discipline specific issues are related to addressing contract documents and planning requirements in Civil Engineering, GDPR in Computer Engineering, Environmental directives in Environmental and Energy Engineering programmes. Lab demonstrations have been used to teach students about conducting engineering practice in a safe manner as to avoid workplace accidents, based on the guidelines set in the Safety, Health and Welfare at Work Act, operating machinery at work set in the 2006/42/EC Directive or for operating

electrical panels stated in the National Rules for Electrical Installations. Dilemmas related to whistleblowing has been a popular topic in the case studies employed, giving rise to discussions related to the protective measures and legislation needed.

For assessing legislative related coverage, the methods employed include exam questions, research projects, design projects and capstone projects, as seen in Table 6. A key issue emphasised by several lecturers is the importance of having assessment that encourages students to “apply legislation and standards to real life examples”. This can be achieved by conducting a risk assessment of a specific product or process, preparing an invention disclosure or a SEA/EIA project in compliance with statutory and public hearings, as well as by integrating legislative requirements in the design of a product. It is also considered important to assess knowledge of various legislative stipulations, by asking students to recall their formulation in exam reports. Critical reflection is encouraged by adopting assessment methods that encourage students to evaluate a specific policy or formulation.

Table 6 Assessment methods incorporating legislative issues

Type	Example
Exam questions	Describe the hierarchy of standards used to ensure compliance with safety legislation Reflect on a specific policy Recall measures for protecting intellectual property
Risk and impact Assessment	Identify hazards as per the international standards Conduct a risk assessment of a product or process Write standard operating procedures for experimental work
Research projects (reports, presentations, posters)	Evaluate policies Preparing SEA/EIA projects for complying with statutory and public hearings Developing an invention disclosure
Design projects	Define core issues relating to intellectual property within a device design Integrate requirements based on existing standards and regulations
Capstone projects	Includes risk assessment rubric. Legislative considerations are encouraged in a contextual section.

6 SUMMARY

While we cannot say that the implementation of sustainability and legislation topics are carried in a systematic and even manner in the programmes that participated in the study, what does emerge is a desire to address ethical issues through their prism. Sustainability and legislation appear to be popular topics used to meet the accreditation outcome purporting to ethics. They also appear to be good candidates for integrating ethics across the curriculum, as they can be tailored to the technical expertise of engineering faculty and appeal to students. An issue that warrants further exploration is how we can use this desire to focus on ethics “as sustainability” or “as legislation” to broaden engineering education and more fully integrate the technical, social, legal and environmental dimensions of engineering in one comprehensive and holistic form of education ([21], [22]).

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