ŌTAUTAHI CHRISTCHURCH AOTEAROA NEW ZEALAND
35TH AUSTRALASIAN ASSOCIATION FOR ENGINEERING EDUCATION ANNUAL CONFERENCE
8-11 DEC 2024
THE ENGINEER AND THE WORLD

Design of an Online Ethics module for Final Year Engineering Students

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ABSTRACT

CONTEXT

There has been an increasing demand for deeper integration of ethics in engineering degrees. Engineers Australia requires engineering ethics to be integrated in all undergraduate engineering programmes. To fulfill this requirement, an online module to refresh engineering ethics and introduce research integrity to final year students was developed at the School of Engineering and Technology at UNSW Canberra.

PURPOSE OR GOAL

The purpose of this study was to design, test and evaluate a new online module for final year engineering students on engineering professional ethics and research integrity. The research questions were: (1) how effectively are the learning outcomes achieved by the module? (2) how well do students engage with the module? (3) how can the module be improved to give better student experience and increase learning outcomes?

APPROACH OR METHODOLOGY/METHODS

The study adopts a Design-Test-Evaluate methodology. The module was delivered online and was self-paced. A pre and post-module survey and quiz were designed to test and evaluate the student engagement and the effectiveness of the module.

ACTUAL OR ANTICIPATED OUTCOMES

There are two outcomes of this study. First, the module itself which can be implemented online with minimal academic workload to support students' education in engineering professional ethics and research integrity. This module was developed and implemented in May/June 2024 as a required component of final year projects for all fourth year engineering students, using a competency approach. The module was developed in collaboration with an Education Designer and has a visually appealing and engaging learning environment. Second, the documentation of the process will provide insights for others who are developing ethics content for undergraduate engineering, and a model for such modules.

CONCLUSIONS/RECOMMENDATIONS/SUMMARY

It is hoped that the module will support learning in the areas of engineering ethics and research integrity, and an increased appreciation for the value of ethics in engineering. This will allow the students to make informed and ethical decisions in their final year project, and as practicing engineers in the future.

KEYWORDS

Engineering ethics, Engineering Education, Online learning

Introduction

Italian architect Stefano Marzano states, ‘Every time we design a product, we are making a statement about the direction the world will move in.’ This also applies to the field of engineering and it is prudent to remember that engineering transcends a technical endeavour, with important social, political and ethical dimensions (Martin, 2019). Thus, it is critical to train engineering professionals with strong foundations in ethical and moral practice.

UNSW Canberra provides a university education to the trainee officers of the Australian Defence Force Academy (ADFA). 90% of the cohort are uniformed defence trainee officers and a few civilian students round out the student cohort. Since all ADFA trainees and most of the civilian students graduating from UNSW Canberra end up working on defence-related engineering projects, a strong moral and ethical education in defence and engineering is paramount. Until now, the graduates of UNSW Canberra used a mandatory course on military ethics as the sole form of training in ethics. However, upon the recent recommendations of Engineers Australia, it was decided to incorporate engineering ethics for the students along with the military ethics course. This paper describes the design and delivery of one of the four modules developed for providing engineering ethics education to the graduates at UNSW Canberra; the fourth-year module on Engineering Ethics and Research Integrity.

Background

Over the last few decades, there has been an increasing demand for deeper integration of ethical material into engineering curricula at the university level (Taebi & Kastenberg, 2019). Davis (1999) explains that “teaching engineering ethics can lead to increased ethical sensitivity, increased knowledge of relevant standards of conduct and improved ethical judgement and ethical will-power.” Herkert (2000) also points out that engineering ethics expands beyond the key concepts of ethical frameworks to the notion of professional responsibility for engineers (higher sense of responsibility that comes with specialist knowledge about their field). In industry, responsible engineers are expected to create and implement safe and useful technologies while respecting the autonomy of clients and the public (Herkert, 2000; M. Martin & Schinzinger, 1996). The US Accreditation Board for Engineering and Technology (ABET) among other engineering accreditation bodies, requires all engineering programmes to include engineering ethics and social responsibility training in their curricula as a required competency demonstrated by students. Engineers Australia also requires ethics of engineering integrated in undergraduate engineering programmes in Australian universities.

In recent years, several high-profile cases of engineering malpractice by major corporations in civil and government projects have been brought to light (recall the Volkswagen cheat device case, Boeing 737 Max among others). To ensure future engineering professionals learn from these mistakes and are well-prepared to tackle ethical dilemmas (Newberry, 2004) and other professional and social responsibilities that clash with the economic and financial goals of their employers, a robust background of engineering ethics education is paramount (Xie & Luo, 2022). The codes of ethics for engineers across the globe cover these principles, accountabilities, and responsibilities according to the current system of values and ethics guiding the field of engineering.

Engineering Ethics Education in Defence

In spite of a robust military ethics education, a study of the scores of the United States Military Academy (USMA) graduates in environmental engineering showed a below average score on the ethics section of the Fundamentals of Engineering Exam between the years 2002 and 2007(Davis & Butkus, 2008). Davis and Butkus (2008) state that while a robust military ethics programme may have a number of elements in common with the Code of Ethics of practicing engineers, (the National Society of Professional Engineers (NSPE) in the case of USMA), a robust military ethics education may be insufficient to prepare a graduand for the engineering profession with a lack of education/instruction in stakeholder relationships and engineering roles.

EA Requirements

Engineers across the world are held accountable for professional and ethical conduct. Similarly, EA holds engineers in Australia accountable for ethical and professional conduct (Stage 1 competencies for professional engineers, EA). Until now, UNSW Canberra largely relied upon the compulsory military ethics course that students are expected to complete to meet these requirements. This consideration of military ethics was deemed inadequate by EA and UNSW Canberra was advised to include more engineering ethics in the undergraduate engineering programmes. Hence, following this advice, the School of Engineering and Technology is working to integrate four modules of engineering ethics into the engineering curriculum based on the EA recommendations and Bucciarelli's (2008) advice on ways to integrate engineering ethics in the engineering curriculum. This new module will incorporate the missing engineering ethics in the course along with the military ethics course that students normally complete.

Design of the module

Bucciarelli (2008) suggests that the essential route to integrate ethics in the realm of engineering education is to reform the whole of the engineering programme to enable the understanding of the social as well as instrumental challenges of contemporary professional practice and its implications to the social and ethical behaviour of the practicing engineer (Bucciarelli, 2008), ideally, through a 3-2 programme (3-year undergraduate and 2-year postgraduate). However, Bucciarelli's (2008) suggestion of a 3-2 programme is not suitable for the current Australian engineering degrees that are a specialised 4-year programme. Nor is it always practical to completely reform the entire curriculum.

After consulting with the Deputy Head of School (Education) and the Director of Undergraduate Studies for the School of Engineering and Technology, it was decided to integrate four modules of engineering ethics into the engineering degree programme, one in each year of the degree.

1. First Year – Introduction to engineering ethics, an overview of the social responsibilities of the engineering profession.
2. Second Year – Ethics of Engineering Design (technical ethics).
3. Third Year – Ethics in workplace and decision-making (professional ethics).
4. Fourth Year – Research Integrity (including ethical usage of AI in industry and research).

Without these new modules, most of the students who will be graduating from UNSW Canberra in 2024 and 2025 would have had only approximately 2 lectures on engineering ethics in their entire degree, and some would not have had any training/education in ethics except for the mandated military ethics course. To overcome this lack of engineering ethics in the current curriculum, a self-paced online module covering the basics of engineering ethics, EA's Code of Ethics, ethical decision-making frameworks (deontology, utilitarianism, Aristotelian ethics) and various case studies of unethical engineering was created with the help of an Education Designer for an appealing and engaging design. It also covers an introduction to the principles of research integrity. This self-paced online module was set up in such a way that all components including assessment can be completed without any input or monitoring required from course conveners or other academic staff.

Learning Objectives

Since this module was the first introduction to engineering ethics for the 2024 fourth year cohort, and self-paced, online and unmonitored, it was decided that its learning outcomes will be at multi-structural and (to a certain degree) relational levels in the SOLO taxonomy (Biggs & Collis, 2014). The students are not expected to theorise and generalise these concepts. However, a certain level of reflection about the application of these concepts in their honours' project and their future positions as professionals is expected. The content of the module for 2024 includes Professional Ethics and Research Integrity, rather than just Research Integrity which is the longer-term plan for the module. It was decided to include Professional Ethics in this module in 2024 to ensure this

cohort would have some exposure to it before graduating. The intention for 2025 onwards is to extend and divide the module described here into the third- and fourth-year modules listed above.

The learning objectives for this module are as follows:

1. Describe the principles of the EA Code of Ethics and Research Integrity.
2. Apply ethical frameworks for decision-making.
3. Reflect on the importance and application of engineering ethics and research integrity by engaging in real-world case studies.

Harris *et al.* (1996) provides a list of nine objectives attained by integration of ethical theories and ethics education in engineering education. This module, due to its online nature, cannot integrate all possible objectives. Instead, this module aims at achieving the objectives of: helping students recognise and analyse key ethical concepts, principles and issues; increasing student sensitivity to ethical concerns and encourage students to take ethics seriously (Harris Jr, Davis, Pritchard, & Rabins, 1996). These objectives are shown in Table 1. The cells marked in blue denote the objectives that will be achieved or partially achieved with this module.

Table 1 – Objectives of Integrating Ethical Theory into Education (Harris Jr *et al*., 1996)

Emotional Engagement	**Intellectual Engagement**	**Particular Knowledge**
Stimulate the ethical imagination of students.	Help students engage with ambiguity.	Increase knowledge of relevant standards.
Help students recognise ethical issues.	Encourage students to take ethics seriously.	Improve ethical judgement.
Increase ethical will-power.	Increase student sensitivity.	Help students analyse key ethical concepts and principles.

Module Content

The module begins with a pre-module survey and a pre-module quiz. This is followed by the main content of the module. The module concludes with a post-module quiz and a post-module survey to analyse the effectiveness of the module and obtain students' views on the module for its improvement. The two quizzes and the main module content are mandatory parts of the module, whereas the surveys are voluntary. Human Ethics approval was obtained to use the results from the surveys for research purposes (iRECS6259), approval to use quiz-data is pending (iRECS6662). The course was created and implemented completely in the Learning Management System – Moodle (Figure 1) and completion of the module is a mandatory requirement to pass the Final Year Project course.

Pre-module and Post-module Surveys

The pre-module survey was designed to understand what level of awareness of the EA Code of Ethics and Research Integrity the students had prior to undertaking the module. The surveys were voluntary, and students had the option of not participating in the survey. The reason for doing a pre-module and a post-module survey was to gauge the difference, if any, the module made to the students' understanding of engineering ethics and research integrity.

The pre-module survey consisted of five Likert-scale questions to assess the students' views on engineering ethics and research integrity and its importance in their future professional careers. Students had to answer the questions on a 6-point scale (strongly disagree, disagree, moderately disagree, moderately agree, agree, strongly agree). These questions are shown in Figure 2.

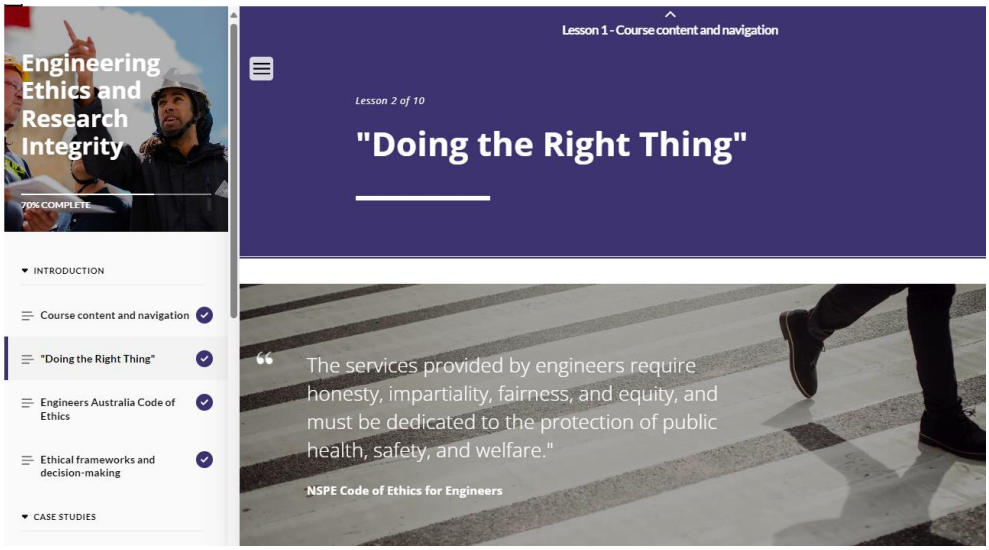

Figure 1 – The interface of the module

The post-module survey was comprised of the exact same questions from the pre-module survey (Figure 2) in addition to three questions that asked the students about what the most enjoyable part of the module was and why, what could be improved in the module and how, and for any other comments. The surveys were designed to take less than 5 minutes to complete to minimise inconvenience to students.

The data collection from these surveys is under progress. It was expected to be completed by June 2024. However, the data collection took longer than expected due to delays in Human Ethics Approval (iRECS6662) and extended beyond the timeframe of this paper, and hence, could not be included in this paper. Thus, the main focus of this paper is the design of the module and the test metrics that will be employed for the evaluation of this module.

	Strongly disagee	Disagree	Moderately disagree	Moderately agree	Agree	Strongly agree
Ethics is important to me as an engineer	○	○	○	○	○	○
I am well aware of the Engineers Australia Code of Ethics	○	○	○	○	○	○
I understand the importance of ethical decision making and its role in engineering	○	○	○	○	○	○
I am confident that I can make ethical decisions in engineering	○	○	○	○	○	○
I am well aware of the importance of research integrity	○	○	○	○	○	○

Figure 2 - Likert-scale modelled questions in the surveys.

Module Learning activities

Herkert (2000) describes the different pedagogical approaches used for teaching ethics to engineers –

1. Ethical frameworks (codes of ethics and philosophical theories)
2. Ethical case studies and
3. Online ethics sources

The current module developed for UNSW Canberra engineering students includes all three approaches mentioned above. The module utilizes ethical frameworks and the Engineers

Australia Code of Ethics, three case studies in different branches of engineering (mech/aero, civil, electrical), and finishes with an additional introduction of students to principles of research integrity that align well with their final year project. The module also provides extra references and sources to learn more about engineering ethics and its significance. The students are introduced to the concept of engineering ethics through a PBS – Crash Course video on engineering ethics (PBS, 2018). This video largely describes the Code of Ethics for the American Society of Civil Engineers, however, the context provided is applicable globally.

Students cannot proceed to the next page of the module until they have completed the current page. They have to open each content page at the very least and answer a series of short factual comprehension questions before proceeding to the next section. They cannot undertake the post-module quiz and survey until and unless they have completed the learning activities.

EA Code of Ethics

Every engineer working in Australia is expected to abide by the EA Code of Ethics and Guidelines on Professional Conduct. Thus, the module's core content begins by providing a refresher on the EA Code of Ethics and its four principles (integrity, competence, leadership, and sustainability). The content extends the principles mentioned in the EA Code of Ethics by consulting other engineering codes of ethics across the world and drawing from resources such as the Sustainable Development Goals (SDG) of the UN and the role of engineering to the SDG context (United Nations).

Ethical frameworks for decision-making

A debate on the merits of a code-based approach compared to a morality-based approach to ethics in engineering has been ongoing for a substantial period of the late 20th century and continues even today. However, a consensus seems to suggest a theory-modest approach wherein code and case-study analyses are augmented by introducing moral reasoning (Herkert, 2000; Lynch, 1997). Following this line of thought, three different ethical frameworks – virtue ethics, deontology, and utilitarianism are introduced in the module. These frameworks are introduced in the form of written text and PBS – Crash Course videos available on YouTube (PBS, 2016a, 2016b, 2016c). The rationale behind using videos to explain ethical frameworks was to keep it light and brief instead of bombarding the students with extensive material from ethicists.

Case Studies

The most popular and probably the more engaging method to teaching ethics is through case studies (Harris Jr et al., 1996). Although hypothetical cases have been created for teaching engineering ethics as used in the first-year module developed by Abdullah *et al.* (2024), to be most effective they need interaction between students so they can compare and contrast their thoughts regarding the ethical dilemma in question. This was not possible through an unmonitored online module. Hence, it was decided to include three past case studies of unethical engineering practices that led to major issues and what scholars believe the engineering field has learnt through these cases. This allows students to engage in comparing their thoughts to the ones provided by scholars. Since the four streams of engineering taught at UNSW Canberra are civil, mechanical, aeronautical, and electrical; the three case studies chosen focused on these fields of engineering to provide context within their degree and increase interest in reading those case-studies. The case studies chosen were the Ford Pinto case, the collapse of the Hyatt Hotel, Kansas, and the Boeing 737 Max's MCAS system. Although primarily chosen to evoke the interest of engineering students from different fields of engineering, these case studies also focus on different dimensions of engineering that led to failure/disaster allowing students to understand the ill effects of unethical engineering practices. Students are required to complete all three case studies, and hence be exposed to the specific dimensions of engineering ethics relevant to each case.

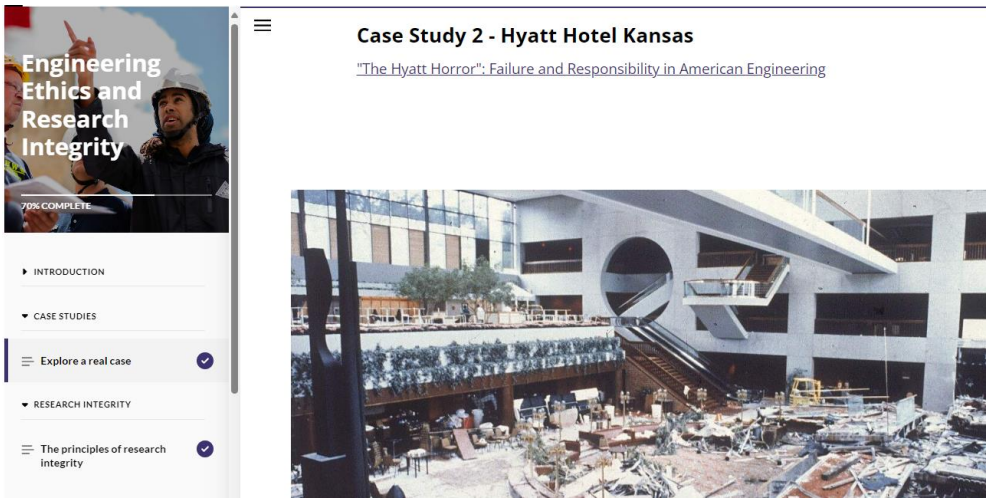

Figure 3 – An example of the interface for case studies (Case study 2 – Hyatt Hotel, Kansas)

The case studies were provided to students as peer-reviewed articles. The idea behind using articles for case-studies was to provide practice at reading journal articles that is expected to help them with their final year project. To ensure students were engaging with the material, factual comprehension-based questions regarding each article were placed after each article. Although the analysis of the surveys conducted is continuing, initial responses of students suggest that students enjoyed the case studies the most. One of the quotes from the post-module survey mentions –

"The scenarios because it was interesting to read about engineering failures."

The initial response also suggests students would like more engagement and discussions on the ethical dilemmas and ethical concerns in the case studies rather than the factual, comprehension-based questions.

Research Integrity

The final section of the module introduces the concept of research integrity, and the eight principles of research integrity explained in the Australian Code for Responsible Conduct of Research developed and published by the National Health and Medical Research Council (NHMRC) in conjunction with the Australian Research Council (ARC), and Universities Australia (National Health and Research Council, 2018). This section also expands on students' responsibilities as researchers for their final year project by providing explanations and expectations for each principle of research integrity in a university context. A sample case of research misconduct and its consequences is provided in this section.

Pre-module and Post-module Quizzes (Assessment task)

The assessment for this module was required to be unmonitored and automated while also assessing student learning at the level of the learning outcomes. Considering the constraints on the assessment and the LOs, a quiz with 14 multiple-choice questions was created. The questions ranged from a basic and factual understanding (listing, describing) of the EA Code of Ethics and principles of research integrity to identifying the principle that needs to be applied in a scenario. A sample question included in the quiz is given below. The same questions were used in the pre-module and post-module quizzes.

"I make sure I get good statistical advice when planning my research so that I am confident my data analysis methods are appropriate." Which principle of the Australian Code for Responsible Research does this fall under?

a. Honesty b. Accountability c. Rigour d. Transparency

Students were required to complete this quiz with a minimum score of 80% to demonstrate their competencies in engineering ethics and research integrity. They were allowed an unlimited number of attempts to complete the ethics module. However, if they do not score 80% or higher in the quiz, they are required to go through the module content again before re-attempting the quiz. This decision was made to ensure that the students have to, at the very least, skim through the important concepts mentioned in the content.

Conclusion and Future work

This paper summarizes the learning outcomes, content design and assessment design for an online engineering ethics and research integrity module for final year engineering students. This module is self-paced and fully automated and does not add to the workload of academics while still providing opportunities for students to refresh their knowledge of engineering ethics and learn more about the principles of research integrity.

The next part of this study is to analyse the quantitative and qualitative data gathered through the pre- and post-module surveys and quizzes. The intention is to analyse the student engagement and experience with this module and revise the module before its next iteration. Specifically, the idea is to investigate the effectiveness of the module through normalised learning gain, survey data and qualitative data through the comments. It may also be interesting to investigate the effectiveness of research integrity on student performances in their final year project reports through different criteria like supervisors' comments and plagiarism reports.

The current design, as mentioned previously, is a part of the integration of engineering ethics in all engineering degrees at UNSW Canberra, with the aim of having at least one ethics module every year of the degree. It is acknowledged that this online module lacks opportunities for discussion among students and between students and staff, including discussion of possible responses to ethical dilemmas, which is an important part of ethics education. To overcome this, the first-year module 'Introduction to Engineering Ethics' (Abdullah, Pawar & Wilson, 2024) and the second-year module of 'Design Ethics' will be conducted face-to-face with ample time allowed for discussions and reflections. The second-year face-to-face module (design-ethics) is under development. The third-year online module (work-place ethics) will be an expanded version of the module presented here, without the research integrity component. The fourth-year research integrity module will be expanded to include ethical usage of Artificial Intelligence (AI) in research. These modules will be deployed into the curriculum in 2025 so that all our engineering graduates from the 2028 cohort and onwards will have completed all four modules, and from 2024 all graduates will have completed at least one module.

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