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Development of an Ethics Module for Australian Undergraduate Engineering Students

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ABSTRACT

CONTEXT

It is important, given the impact that engineering can have on people's lives, that Australian engineering students are aware of their professional and personal responsibilities before entering the profession. One of the Engineers Australia recommendations from the most recent accreditation round at UNSW Canberra was to increase the amount of engineering ethics taught throughout its undergraduate programs.

PURPOSE OR GOAL

The purpose of this study is to develop and deliver an ethics module to first-year electrical engineering students, and evaluate the effectiveness of the module. This evaluation then informs the refinement of the module before it is implemented across all the engineering programs at UNSW Canberra. This is part of a broader project to develop new ethics modules to incorporate engineering ethics into all year levels in the degree.

METHODS

The design of the module was informed by similar programs at international universities and existing pedagogical models for the teaching of ethics at other Australian universities. The module was designed to be taught face to face over approximately 5 hours of lectures and two hours of tutorials. Quantitative and qualitative data was collected via pre- and post-instruction surveys to investigate both student experience and learning. Qualitative data from surveys was analysed using a grounded theory approach to identify themes, and triangulated against classroom observations.

OUTCOMES

The survey data showed that students enjoyed the module, and that it increased their confidence in applying engineering ethics, as well as their familiarity with the EA Code of Ethics. The single strongest emerging theme in the qualitative data was the value of in-class discussions. Classroom observations reinforced this. But it was also observed that students were reluctant to consider ethical viewpoints other than a simplistic deontological "follow the rules" approach.

CONCLUSIONS

The implementation of the module was more successful than anticipated, with high levels of student engagement. Hence it may provide a useful model for the development of similar modules, at UNSW Canberra and elsewhere. The finding that our students revert to a deontological ethics approach highlights the importance for UNSW Canberra of increasing the engineering ethics content taught rather than relying on military ethics instruction.

KEYWORDS

Engineering Education, Ethics Education; Undergraduate.

Introduction

Context

Engineers have a huge impact on everyone's life; from the technology in our pockets to major infrastructure that we use every day, to the medical equipment in our hospitals. Every day we all use systems and devices that were designed by engineers. Given the power that engineers have, it is therefore crucial that engineers are not only competent, but trustworthy. So, ensuring that future engineers know their ethical obligations and how to make ethical decisions is an important part of engineering education.

In the UNSW Canberra context, it is particularly important that the engineering undergraduates receive appropriate training in the ethics of engineering. UNSW Canberra provides a university education for Australian Defence Force Academy (ADF) trainee officers and a small number of civilian students. Graduating ADF engineers go on to work with military platforms across the Army, Navy and Air Force, and it is common for the civilians to go on to work in defence related industries on projects dealing with military infrastructure and capabilities. These graduates need to be well equipped to solve complex moral challenges. Some ADF graduates also become civilian engineers at some later stage in their careers after leaving the defence force, so they need to be familiar with engineering ethics in that civilian context. Engineering ethics appears in the stage 1 competencies of professional engineers under Professional and Personal Attributes (Engineers Australia 2019b) so is a required part of the degree.

However, until prompted by recommendations of a recent Engineers Australia (EA) accreditation review, we relied almost entirely on courses in military ethics to provide the ethics education for our engineering students. In response to that EA review, we are now developing four ethics modules to be taught as part of our engineering degree for all undergraduate students. These are Introduction to Engineering Ethics (first year), Design Ethics (second year), Engineering Workplace Ethics (third year) and Research Integrity (fourth year).

The first two of these modules will be taught face to face as part of core courses in each discipline, adapted to suit the discipline by choice of hypotheticals and case studies. These modules will be assessed within the courses, and contribute to course grades. The second two modules will be taught online asynchronously. Completion of the Engineering Workplace Ethics module will be a requirement for completing engineering work experience, and completion of Research Integrity for completion of final year projects (Pawar et al., 2024). Students must complete these two modules to graduate.

This paper describes the first module, Introduction to Engineering Ethics, which was developed and evaluated by an undergraduate student (author AA) for his final year project. The module content was based on existing content from the Introduction to Aeronautical and Mechanical Engineering Course, but significantly expanded. It was taught in semester 1, 2024 in the Introduction to Electrical Engineering course, and will be refined based on this analysis and taught in all "Introduction to…" courses from 2025.

Literature review

Ethics and engineering ethics

Ethics is a branch of philosophy that systematically explores and studies moral principles and values (Singer, 2023). Ethics can be divided into three branches: metaethics, normative ethics and applied ethics. Applied ethics is the application of normative ethics. Engineering ethics is a branch of applied ethics, providing a framework for ethical decision making in the context of engineering projects and workplaces. It applies specifically to engineers, informing decision making in a professional context, as distinct from a personal context (Harris et al., 1996).

Within normative ethics, there are three common moral frameworks: deontology, utilitarianism and virtue ethics. Deontology is the ethics of duty (Heinzelmann, 2018). The underlying principle is that the correct moral approach is to follow the *rules*. Naively, one might expect a rules-based

approach to sit most comfortably in a military context. However, such an approach is challenged in the military ethics course taught by a civilian academic at UNSW Canberra that is taken by all ADF undergraduates in their second or third year. In contrast, utilitarianism emphasises the *outcomes* of one's actions, with the aim of achieving the greatest good for the greatest number (Mill, 2016). Finally, virtue ethics emphasises acting virtuously, and associates ethics with the *character* of the person acting or making decisions (Van Hooft, 2014), and decisions based on virtue ethics may start with the question "what would a *good* person do?".

Engineering ethics, as applied ethics, draws on both deontology and utilitarianism. This can be seen in the EA Code of Ethics (Engineers Australia 2019a) and Guidelines on Professional Conduct (CEGPC) (Engineers Australia 2019b), which stress the need to serve the community while also laying down specific rules about what an engineer can, and cannot, do. For example, the CEGPC highlights the importance of developing sustainable engineering solutions via ethical and just practice and lays out rules about practicing only within the bounds of one's competence.

While there are certainly overlaps between military ethics and engineering ethics, there are also significant differences. For example, a commander may over-rule a decision as to whether a vehicle meets engineering safety standards. The need for engineering ethics education in addition to military ethics education for defence force engineers has been identified by Davis and Butkus (2008). They suggest that even a robust military ethics course needs to be expanded to include concepts such as, but not limited to, employer, client and engineer relationships.

A majority of the engineering accreditation bodies across the world expect engineers to follow a code of ethics and professional conduct. For example, the National Society of Professional Engineers (USA) publishes and promotes the Code of Ethics for Engineers (NSPE, 2019), and the Engineering Council in conjunction with the Royal Academy of Engineers (UK) has developed a Statement of Ethical Principles for the Engineering Profession (Royal Academy of Engineering, 2017). For the purpose of developing an Engineering Ethics Module for students at UNSW Canberra, we used the EA Code of Ethics and Guidelines on Professional Conduct (Engineers Australia 2019a, 2019b) as the basis for the module as it is the code that our graduates will have to abide by while working in Australia, and the EA is our accrediting body.

Engineering ethics education

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) and engineering ethics has been identified as an integral component of engineering education (Lim et al., 2021). For example, the US Accreditation Board for Engineering and Technology (ABET), requires all accredited engineering and technology programs to include engineering ethics and social responsibility modules (ABET, 2023) and the Fundamentals of Engineering exam which is a requirement of licensing as a professional engineer in the United States includes ethics.

The push to increase ethics education for undergraduate engineers has in part been driven by high-profile cases of engineering malpractice (Xie & Luo, 2022). But as Harris et al. (1996) point out, it is not just "the long and familiar list of tragedies, disasters, and scandals" that should be driving the increase in ethics education, but the many decisions that engineers will make, including in their early years as practicing engineers, long before they are making decisions that could lead to a news-worthy disaster. They will encounter complex ethical dilemmas, and engineering ethics education is crucial to ensure they have the tools required to solve them (Newberry, 2004) and graduates need to be aware of their professional and personal responsibilities from the beginning of their careers (Benlahcene et al., 2022). Hence, an understanding of engineering ethics cannot wait until graduates are in the workplace.

Harris et al. (1996) provide a comprehensive list of nine objectives for engineering ethics education, which includes improving ethical judgement, but also "ethical willpower". These nine objectives were later classified into three groups: emotional engagement, intellectual engagement and particular knowledge (Newberry, 2004). The design of the module, described below, aimed to support all three types of objective.

Numerous pedagogical methods have been developed and used to teach engineering ethics, however, there is a lack of consensus on the optimal way to deliver ethics material to students (Beever & Brightman, 2016). Pedagogical approaches are generally either theory-based, focussing on principles and guidelines, or, more commonly, case-study based, often focussing on examples where engineers have failed to demonstrate ethical-decision making with disastrous results (Bairaktarova and Woodcock, 2017). Bairaktarova and Woodcock (2017) found that educators prefer the case-based instruction method, as it more effectively engaged students.

Bairaktarova and Woodcock (2017) also summarise various ways of incorporating engineering ethics education into the curriculum – as a stand-alone course, spread throughout the curriculum (for example at George Washington University (GWU, 2024)) or as modules associated with specific stages. They note that stand alone courses are often taught by humanities academics rather than engineers (as is the case at UNSW Canberra) so may lack connection to engineering professional ethics. But when spread throughout the curriculum, ethics is often not assessed, so its importance is undermined. With this in mind, the decision was made to use a modular approach, with one module at each year level, and with assessment of the modules contributing to either course level grades, or overall competency hurdles.

The following section describes the design of the first-year Introduction to Engineering Ethics module, as carried out by a final year undergraduate student (first author, AA).

Methods

Design of the module

The aim of the first-year module Introduction to Engineering Ethics was to stimulate students' interest in engineering ethics (intellectual engagement), encourage them to care about behaving ethically (emotional engagement) and give them some basic tools for making ethical decisions (knowledge) (Newberry, 2004). The learning outcomes for the module were developed based on Bloom's taxonomy (Forehand, 2010), to stretch from lowest to mid-level outcomes, and focus on the third aim (knowledge) as measurable through assessment tasks:

1. Develop baseline knowledge of the ethical and professional responsibilities that are required to practice engineering
2. Describe the EA "Code of Ethics and Guidelines on Professional Conduct"
3. Explain ethical theories and their applicability to the workplace
4. Apply ethical reasoning in line with Australian Standards

Later modules will address higher-level learning outcomes.

The module was designed to be delivered face to face in 5 one-hour lectures and 2 one-hour tutorials, as this was enough to cover the content and allow ample time for discussion but still fit into the course schedule for Introduction to Electrical Engineering. The content drew on an existing two-lecture introduction to engineering ethics, but was substantially expanded using the EA CEGPC, as well as hypotheticals created by the undergraduate student researcher. The hypotheticals were developed by drawing on his experience in the military, discussions with defence force officers and examples in the literature and media.

The lectures followed a pattern of a stimulus hypothetical which students discussed in groups, followed by direct instruction on the EA CEGPC, then a discussion question. The discussion of hypotheticals was used to stimulate intellectual and emotional engagement (Newberry 2004). Harris et al. (1996) point out that discussion stimulates the growth of "ethical will power" and that if "students [have] a chance to make ethical judgements, explain them, and compare them with those other students make, the student is more likely to judge well". Hence the discussions were a central part of the module design. Figure 1 shows two example lecture slides.

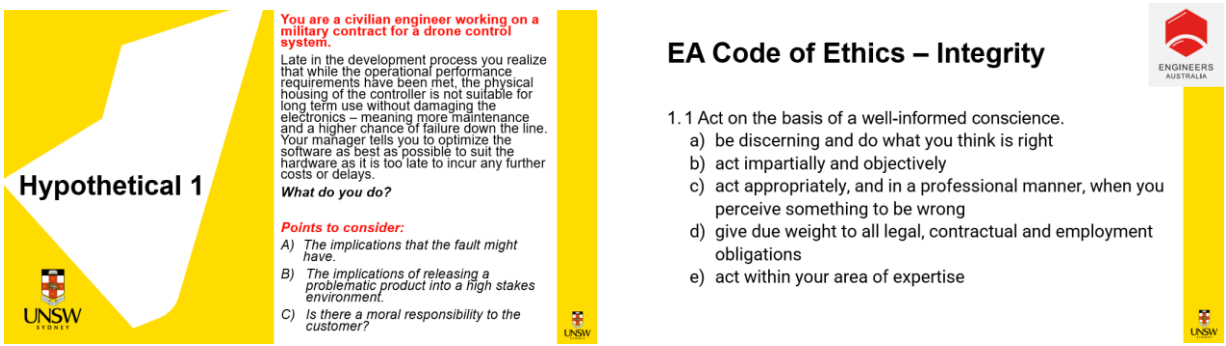


Figure 1: Example lecture slides from the module

Students worked in groups in tutorials to answer questions about the EA CEGP, and discuss a real case study, of the type Harris et al. (1996) refer to as “tragedies, disasters and scandals” to emphasise that there can be catastrophic outcomes when ethical principles are not adhered to.

The learning outcomes were assessed as part of the existing ongoing formative assessment in tutorials, as well as on a class quiz (summative assessment) to ensure that students took the module seriously. The existing tutorial assessment is a weekly submission of a solution to a problem to an online discussion board, and a review of another student’s submission. For the ethics tutorials, students were asked to write a short hypothetical ethical conundrum, of approximately 150 words for the first week, finishing with “what should you do?”. For the second week, they were asked to either respond to someone else’s hypothetical giving reasons for their choice, or feed the hypothetical into ChatGPT and then copy its response to the discussion board and provide a critique of that response. The class quiz included a mixture of multiple choice and short answer questions, which required recall of the EA CEGPC.

Test and evaluation of the module

The module was presented approximately half-way through semester 1, following and followed by technical content. It was presented by one of the two course lecturers, who has an extremely engaging lecture style and frequently calls for student contributions. Hence the very interactive nature of the module was not at odds with the style of the course.

The module was evaluated using two surveys (pre- and post-instruction) and classroom observations. Ethics approval was obtained by the student researcher for the surveys and classroom observations (UNSW iRECS 5920). Unfortunately, use of assessment data by the undergraduate research student, even de-identified, was not possible at the low-risk level, and a higher-risk human ethics application was beyond the scope of a final year project. However, we can make some general comments on how students performed on the assessment tasks.

The pre-instruction survey consisted of eight Likert scale questions on a six point Strongly Disagree (1) to Strongly Agree (6) scale. The first six questions were repeated on the post-instruction survey (see Figure 2), so that gains in (self-reported) knowledge and confidence could be measured. The post-instruction survey included further Likert scale questions typical of course evaluations (see Figure 3a) and three open questions asking what was good, what could be improved, and for any other comments. The responses to open questions were analysed using thematic coding by two researchers independently.

The unobtrusive classroom observations were carried out by the student researcher who took notes during the observations. These were supplemented by observations by a second researcher.

Results

The results reported below are for the survey and classroom observations. Hence they speak to student engagement and self-reported satisfaction and learning. They do not provide an objective

measure of learning. As stated above, it was not possible for the undergraduate researcher to obtain ethics approval to use assessment data from other undergraduate students. However, the course lecturers did comment that students did well on the questions on ethics in the class quiz, and that their responses to the assessed tutorial questions were well considered and indicated a high level of engagement.

Quantitative Survey Data

From a class of 39 students, 35 completed the pre-instruction survey and 32 completed the post-instruction survey.

The six repeated questions allow us to see how students' knowledge, attitude and confidence about ethics is affected by the module. For each of these questions we saw a significant ($p<0.01$) positive change using a two-tailed test. Figure 2 shows the average pre- and post-instruction score for each of these matched questions. As might be expected, gains are greatest on content specific questions. As can be seen, students had some familiarity with theories of ethics before taking the module. Half the class agreed (at some level) that they were familiar with theories of ethics. Given that the class is 95% ADF trainees, all of whom do some military ethics early in their training, we expected close to 100% agree on this question. Further, for most of the students who agreed with this question, on a later question they said this came from their high school studies.

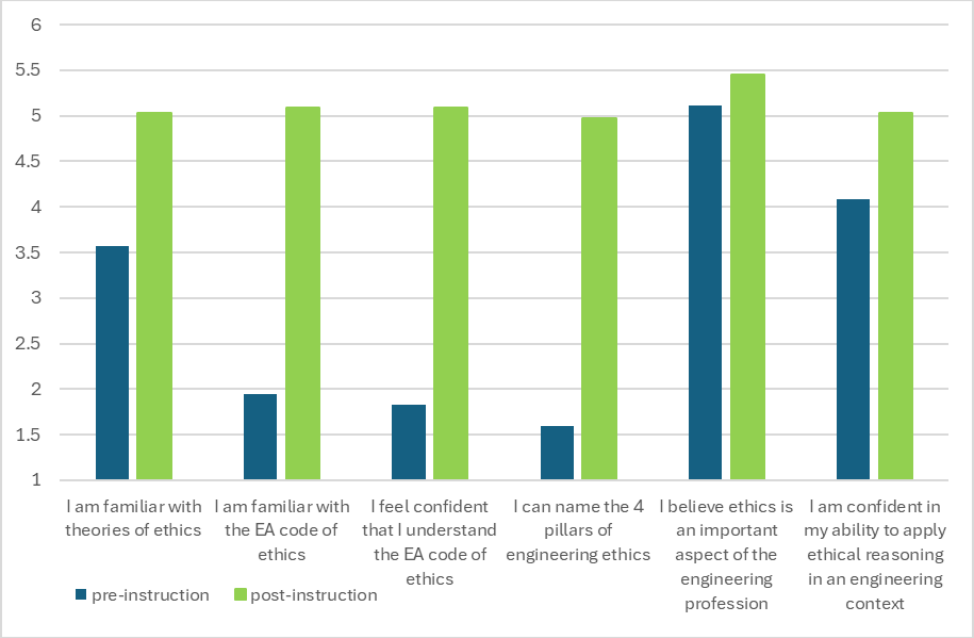
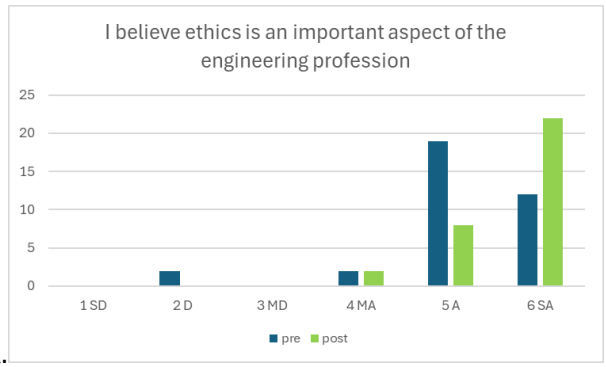


Figure 2: Average response (using SD =1 to SA = 6) for three matched questions pre- and post-instruction survey questions about student learning in the module.

Figure 3 shows the distribution of responses for the two questions with the lowest gains. Prior to the module most students already believed that ethics is an important part of engineering, and many were already confident in their ability to make ethical decisions. This shifted to 100% agree for both questions, but with a stronger post-intruction agreement for the former. It is not surprising (or desirable) that students' confidence did not increase as much - this is only the first of 4 ethics modules that they will take during their degree, and not being over-confident will support them in engaging more effectively with those later modules.

a. 

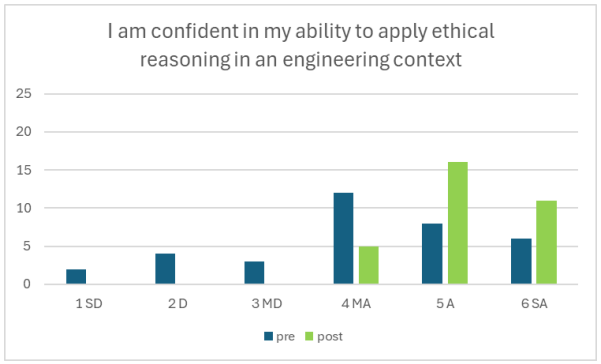
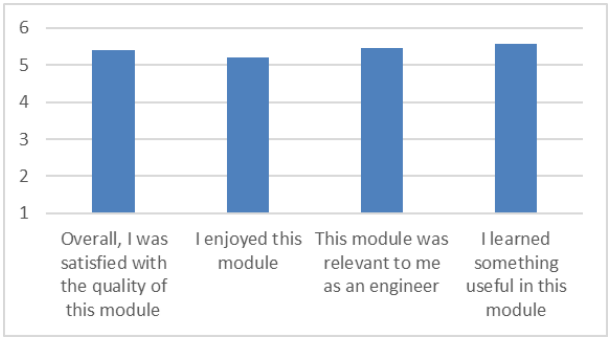
b. 

Figure 3: Distribution of student responses to two survey questions, pre- and post-instruction. The questions used a Likert scale from 1 = Strongly Disagree (SD) to 6 = Strongly Agree (SA).

The post-survey questions asking about student experience of taking the module showed that the module was very well received by students. As can be seen in Figure 4a, the average response for all questions was above 5. The overall satisfaction rating of 5.4 is higher than the faculty average for all courses. For all of the questions but one, 100% of students agreed with the statement to some extent (see example distribution in Figure 3b.) The only exception was a single student who chose Moderately Disagree (MD) for "I enjoyed this module".

a. 

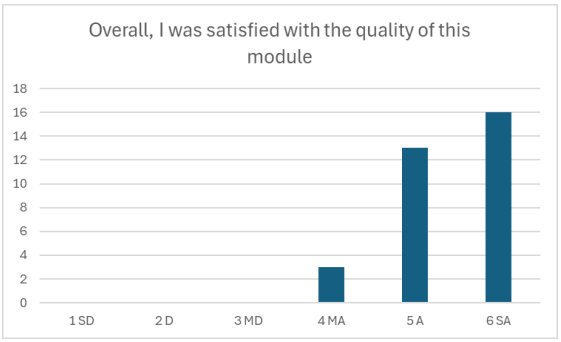
b. 

Figure 4: a. Average response (using SD =1 to SA = 6) for the four student experience questions on the post-instruction survey and b. distribution of responses to overall satisfaction question.

In summary, based on the quantitative data, we can say that the module was a success. But to understand why, and how we can now improve the module before rolling it out into the other degree programs, we need to look at the qualitative data.

Qualitative Survey Data and Classroom Observations

The first open question asked students what the best thing about the module was. Of the 32 students who completed the post-instruction survey, 18 said that the best thing about the module was the group discussions, and an additional 4 mentioned groupwork. Of the 18 who mentioned discussions, 5 explicitly said that they valued seeing multiple perspectives. For example: "The discussion sections. Hearing others ethical opinions and solutions to tackling ethical conundrums was very interesting and increased my ethical problem solving skills". The hypothetical scenarios were also highly valued with 13 students mentioning them, for example "The scenarios and encouragement to develop critical thinking and identify and challenge biases."

This finding that students valued the group discussions of the hypothetical scenarios is supported by classroom observations. In all lectures and tutorials the students were highly engaged, with all students participating within their groups. In fact, the high level of engagement meant that the discussions took longer than anticipated as students were keen to continue debating the various hypotheticals, and also responded at length when called on to give their views to the whole class. This is a class in which there had been group discussions in every lecture prior to the ethics module, taught by a highly engaging and experienced lecturer. So, the unexpected time taken

was not simply because discussions generally take longer than transmitting content, the students were particularly engaged with the ethics content.

However, while the students valued discussion and multiple perspectives, it was noted in classroom observations that often a group's final response to an ethical dilemma would be to "follow orders" - a deontological approach. For example, for the first hypothetical (Figure 1a), all nine student groups came to the conclusion that while they would raise the issue of the drone controller possibly being unfit for purpose, they would not take further action if a supervisor said not to. This was despite general agreement that the issue was a very serious one, and as defence personnel they would be unhappy about having such a system in the field, especially in a combat zone where lives are at stake. One lecturer noted that when she asked a group about what they had done in their military ethics training so far, they said that they had been explicitly taught that the correct ethical approach is deontology. However, it is important to note that these are first years and have not yet completed more than a small amount of their military ethics training, and had not yet taken the challenging third year military ethics course.

The second open survey question asking how the module could be improved did not give strong emerging themes the way the first question did. The most common theme was "more hypotheticals" and in particular more real-world ones. Other suggestions included guest lecturers from the ADF and videos rather than text-based case studies.

While the obvious improvement based on student feedback for future iterations is to therefore include more discussions of hypotheticals, this needs to be balanced against the time taken to deliver the module. At the current length of 7 hours (5 lectures, 2 tutorials), it is already as long as, or longer than, other course conveners are willing to spend on this content. So, extending the module is not a feasible option at this stage. Hence, the intention is to provide more real-world hypotheticals in tutorials, and supplement online readings with videos where possible.

Conclusions and Implications

The stimulus for this project was the Engineers Australia accreditation review, which recommended that we teach engineering ethics explicitly, rather than relying on military ethics education. The observation in class that our students, at least at first year, typically revert to a deontological or "follow orders" approach, supports the EA recommendation.

The students' response to the module was extremely positive. On surveys, they rated the module highly and in class they were strongly engaged with discussions. The finding that students valued discussion and hearing others' points of view will inform the development of the other three modules. The focus on smaller hypotheticals, rather than disaster-based case studies, which is consistent with the recommendations by Harris et al. (1996) to build ethical will-power, was also popular with the students – so not only do we expect it to be effective for their learning, it is also want they want. These initial results are encouraging, but self-reported learning and student feedback surveys are not the most valid measures (Heffernan, 2022) and so in future we intend to explore other mechanisms to evaluate the success of these changes, including assessment.

Overall, the module was successful in stimulating emotional engagement, intellectual engagement and particular knowledge, the outcomes described by Newberry (2004). Hence, we believe that the design of this module, which features a combination of class discussion and direct instruction, with discussions focussed on "everyday" engineering ethics conundrums, may provide a model for the development of ethics modules at UNSW Canberra and elsewhere.

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