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Creating Graduates with SDG Attributes through Engineering Ethics Education

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ABSTRACT

CONTEXT

Engineering ethics is essential to engineering practice. The dominant approach to its education has been focused on micro-ethical issues. Sustainable Development Goals (SDGs) are often regarded as macro-ethical issues relating to engineering practices. It suggests that a holistic approach toward engineering ethics education (EEE) may be worth attempting.

PURPOSE OR GOAL

This paper presents our attempts and concerns of engineering ethics education in practice, in the Australian context. SDG attributes can be used as sources of inspirations of ethics education at the macro-ethical level. In line with some forecasts of engineering education in the future, EEE needs to reach the macro level.

APPROACH OR METHODOLOGY/METHODS

This paper presents a case study on how a technical university in Australia is heading toward a holistic approach of engineering ethics education. In brief, the holistic approach refers to an attempt to disseminate engineering ethics to the undergraduate engineering core subjects, from early-stage professional practice to middle year professional and technical subjects and finally to engineering capstone. This research is also ethnographic in the sense that the researchers serve as participant observers and reflect their own experiences in the course of creating graduates with SDG attributes.

ACTUAL OR ANTICIPATED OUTCOMES

The dominant approach of EEE based on student learning from cases of ethical dilemmas seems to be sufficient to establish ethical awareness and appropriate decision-making at the micro-ethical level. Transitions to the macro-ethical level can take place with some continual guidance on the responses to SDGs. This transition can be assisted by a project based learning experience.

CONCLUSIONS/RECOMMENDATIONS/SUMMARY

Engineering ethics education is better to be diffused into the engineering core subjects and further to engineering capstone. Collaborations between educators seems to be essential. Challenges such as evaluation of student growth in ethical awareness remains.

KEYWORDS

Engineering ethics education, SDG attributes, Ethical engineers

Introduction

Engineering ethics is essential to engineering practice because it synthesises fundamental values and actions of how engineering professionals interact with others in society (Johnson, 2020). Like professional ethics in other professions, engineering ethics has multiple layers of meanings. The code of ethics recognized by Engineers Australia (2019) defines the content of engineering ethics in four dimensions, namely 1) demonstrate integrity, 2) practice competently, 3) exercise leadership, 4)promote sustainability. In this regard, engineering ethics covers both technical and cultural elements. In addition, engineering ethics refers not only to a body of knowledge but also to a series of practices. These two pairs of complex dimensions, technical and cultural, knowledge and practice, consist of the challenges of engineering education toward engineering ethics.

Emeritus Professor Peter Lee, argues in *Engineering change - the future of engineering education in Australia* that

> *“Potential students seeking to study in this new environment must be better informed of the exciting breadth of modern engineering practice and appreciate the greater emphasis on the human elements of engineering. This matches well their desire to ‘make a difference in society’” (ACED, 2021, p. 3).*

This general guideline for future engineering education reforms sheds light on engineering ethics education in Australian universities.

Engineering ethics may be taught as a subject as it is approached in some engineering faculties in the United States (Benya et al., 2013). It may also be taught as an element of the professional practice subjects as some Australian universities have done for their engineering students. Regardless of the curriculum, the central concern on how engineering ethics should be taught may better be placed on the content of teaching. Engineering ethics issues can largely be categorised into two types namely, macro-ethical issues such as social justice as relation to the engineering profession and micro-ethical issues at the level of the individual, such as being honest (Johnson, 2020). Consequently, two questions emerged as how should engineering ethics education incorporate both levels of scenarios and how should educators observe student improvements at two levels?

At the micro-ethical level engineering ethics education (EEE) focused on resolving ethical dilemmas that may appear at a professional context such as how to act appropriately with stakeholders within an engineering project (Conlon & Zandvoort, 2011). Ethical decision making process and regulative framework serve as the knowledge foundation for resolutions to these ethical dilemmas. The application of such knowledge is often taught by analysing real life cases. On the contrary, EEE at the macro-ethical level tends to be relatively pervasive in the sense that critical analysis of technologies may take place in any subjects throughout the entire study period (Newberry, 2009). However, should the same approach be applied to EEE at the macro-ethical level as what has been programmed for EEE at the micro-ethical level?

Engineering practices addressing SDGs are situated at the macro-ethical level because these development goals require some radical changes of technologies as well as to some extent the society which always constitutes the stakeholders of engineering projects (Byrne, 2012). From a methodological point of view, projects to achieve SDG goals are often multidisciplinary or cross-disciplinary. It suggests a comprehensive EEE approach that covers both micro and macro ethical levels needs to be methodologically flexible.

The above mentioned indicators revealed a different perspective toward SDG attributes. SDG attributes can be perceived as ethical elements rather than engineering competencies because the “human elements of engineering” (ACED, 2021) are in fact the prerequisites of engineers’ participation in this course. In this regard, EEE requires a flexible approach to encourage student engagement. This paper presents some reflections on the attempt for the making of such a flexible approach at a technical university in Australia.

Literature Review

The predominant approach to engineering ethics education (EEE) in university courses is through the introduction of a professional code of ethics, and the analysis of case studies (Bairaktarova & Woodcock, 2015; Martin, Conlon, & Bowe, 2021a; Colby & Sullivan, 2008). EEE began to feature in engineering courses from the 1970s (Martin, Conlon, & Bowe, 2021b) but there is a 'paucity of clear documentation of what and how ethics is taught' (Fore & Hess, 2020, p. 1357), and likewise a lack of evaluation of the case study approach to EEE (Davis & Yadav, 2014). What and how EEE is taught encompasses how EEE is assessed, and what the goals of EEE are (Goldin, et al., 2015; Keefer et al., 2014).

Divergent views of the goals of EEE are presented in the literature. Newberry (2004), drawing on Harris et al. (1996), proposes three broad categories of objectives for EEE: emotional engagement, or wanting to make ethical decisions; intellectual engagement, or knowing how to make ethical decisions; and particular knowledge, or being aware of currently accepted guidelines for ethical decision making. In contrast, Paulhus and van Selst (2002) argue that the ability to act ethically is premised on an individual's perception of their level of control over their environment. They describe three spheres of control: personal efficacy, interpersonal control, and socio-political control. Pfatteicher (2001) advocates a far more restricted role for EEE, arguing that EEE should take ethics as the object of study, but when ethical behaviour becomes the objectives of EEE, we stray into preaching, not teaching.

Debates also centre on individualist, or micro-ethical approaches to EEE, and macro-ethical approaches. A focus on individualist/micro-ethical approaches diverts attention from macro-ethical issues (Conlon & Zandvoort, 2011). Organisational culture typically constrains the ability of individual engineers to make ethical decisions (Lynch & Kline, 2000), implying that EEE needs to focus on the ability of engineers to take on roles in relation to macro-ethical engineering issues.

The problems that we face in the twenty-first century have come to be characterised as problems of extensive "systems of systems" (Owens, 1995; Gompert & Isaacson, 1999). The United Nations Sustainable Development Goals (SDGs) are broadly recognised as an enumeration of these major challenges and need to be addressed by integrating the skills and perspectives of multiple disciplines, stakeholders, and representatives of industry, education and government (van den Hoven, 2016; Murphy et al. 2015). These challenges involve complex and interrelated ethical issues that cannot be addressed in isolation.

> *Climate Change, for example, requires us to look at moral motivation, the logic of public goods dilemmas and tragedies of the common, the moral limits of nudging and choice modelling techniques, the limits of stimulating responsible innovation in energy systems by means of financial incentives, the ways to deal with moral compromise that may facilitate political breakthroughs in climate negotiations, designing fiscal measures for industry, thinking about discount rates and future generations in economic models, criteria for fair distribution of risks, and new regulation and new governance models appropriate for grids that allow for decentralized and distributed energy production. (van den Hoven, 2016, p. 1791).*

EEE of necessity needs to lift its gaze from the micro-level and innovations in isolation, and consider ecosystems, socio-technical systems, and the systems of systems that comprise them (van den Hoven, 2016).

Pierrako et al. (2019) advocate a reimagining of EEE to move beyond a focus on extraordinary and difficult dilemmas to "character education [that] focuses on the more ordinary and habitual actions, motivations, and virtues that ultimately play a role in everyday life and prepare us for difficult situations" (p. 1). They identify the case study and code of ethics approach as focussing on two main ethical theories: consequentialism (utilitarianism) which is outcomes focussed, and deontology, which is duties focussed. A third theoretical orientation, virtue ethics, is noticeably absent from much of EEE. “For virtue ethicists, it is not enough to maximise the good effects of our actions (consequentialism) or respect categorical rules and duties (deontology); we must also focus on developing our character, cultivating stable dispositions to act, think, and feel in ways that enable us to do the right thing for the right reasons, in the right ways” (Pierrako et al., 2019, p. 2). Pierrako et al. (2019) cite Cech’s (2014) alarming findings that student’s concerns for public welfare decline over their enrolment in engineering education, and they suggest this points to an uncomfortable possibility that “the character orientations currently selected for and cultivated [in engineering education] are socially and morally unsatisfactory” (p. 4). They posit a number of virtues relevant to engineering: intellectual virtues (curiosity, judgement, reasoning, creativity), moral virtues (compassion, courage, honesty, justice, empathy, hope, kindness), performance virtues (perseverance, resilience, teamwork, diligence, patience), and civic virtues (citizenship, civility, service, inclusion, justice) (p. 5).

Methodology

This paper presents a case study on how EEE education shapes engineering graduates SDG attributes at undergraduate level. The research is designed on the following presumptions. First of all, SDG attributes are recognized as macro-ethical issues. Secondly, education on micro-ethical engineering issues served as the foundation for macro-ethical issues. This leads to the third presumption in the sense that students need opportunities for self-reflection and receive some guidance in order to approach macro-ethical issues. Thus, comprehensive EEE education refers to a pervasive “program” or “process” in which students develop knowledge and put into practice to respond to SDG matters as professional engineers.

This research is also ethnographic. The researchers are subject coordinators of an engineering faculty at an Australian technical university. One of them serves as the subject coordinator for a first year professional practice subject preparing students for their internship which is often the first professional experience of an engineering student. Engineering ethics serves as an essential part of the subject teaching because ethics is the core of professionalism. The other researcher is the subject coordinator for the final year undergraduate engineering capstone.

The Australian technical university is redefining its undergraduate engineering core subjects. Both researchers participated in the consultation. One possible direction that has been discussed in this redefining process is engineering ethics, in general, shall be disseminated across subjects at different stages such as engineering communication, professional practice, humanitarian engineering, technology & society, engineering design and capstone subjects.

The researchers also serve as academic advisors supervising capstone projects. Examples presented in this paper are real life “cases” collected via participant observations through class activities and supervisions, over the past 3 years. In this regard, this paper is a collective reflection and dialogue between the authors about teaching and learning experiences that inquire into the extent to which our practice can facilitate student transitions. The case presented in this paper refers to an attempt to change EEE practices at this university.

Teaching and Learning Practice

Professional practice is introduced in this engineering faculty’s undergraduate and postgraduate coursework degrees in the first year of enrolment. Students are encouraged to start to develop their professional identity and professional network as early as possible in their degree studies. Students enrol in a 6-week program that focuses on key professional engineering competencies mapped against Engineers Australia’s Stage 1 Professional and Personal Attributes (Competency Standards 3.1 - 3.6), that “represent the profession's expression of the … professional skills, values and attitudes that must be demonstrated at the point of entry to practice” (Engineers Australia, 2019, p. 1.). Of particular relevance to this paper is Element of competency *3.1. Ethical* *conduct and professional accountability*, which also encompasses occupational health and safety practice.

At this early stage, our EEE practice resembles the dominant practice in the field that the studies in our literature review report upon (Bairaktarova & Woodcock, 2015; Martin, Conlon, & Bowe, 2021a; Colby & Sullivan, 2008). The Engineers Australia *Code of Ethics* is introduced, and we have a bank of case studies written by previous students based on ethical conundrums they faced during their internships. Students are also required to read an excerpt titled 'Ethical Theories' from *Engineering your future: An Australasian guide* (Dowling et al. 2020, pp. 143-147) that briefly compares ethics and morals, and describes ethical egoism, utilitarianism, duty ethics, rights ethics and virtue ethics, and an excerpt from Longstaff (2017, pp. 1-37). Students are asked to analyse the case studies and then to reflect upon which ethical approach their analyses of the case studies most closely represents. In this respect, we have approached ethics as the object of our study (Pfatteicher, 2001), but in the authors' collective reflection and dialogue we are left wondering about the extent to which this produces engineers with the capacity to act ethically.

The assessment task associated with EEE in this program requires students to reflect in writing upon a time when they faced an ethical dilemma. For this they use Ullmann's (2017) six levels of reflection to guide their writing. These six levels can be grouped into four stages or reflective moves: recount of experience, introspection (feelings, beliefs, difficulties), perspective, and lessons learned. In the perspective phase, students are required to synthesise their experience with ideas from their reading (Bennet, n.d.). Once again, in our collegial conversations the authors ponder what is actually being assessed here: ability to act ethically, or ability to analyse ethical conundrums? We also reflect upon the micro-ethical nature of this approach, and the absence of the macro.

At the final stage, especially in the engineering capstone subjects, we witnessed some transcendence of student's ethical awareness to the macro-ethical level. The engineering capstone project takes two semesters with the first semester as the preparation stage and the second semester as the delivery stage. In the preparation phase, with an academic supervisor, students define a research question followed by applying an appropriate research methodology. These student projects fall into three main streams. The first category appears as engineering scientific research projects based on experiments and or quantitative data analysis. The second category is prototype design and design modifications aiming at prototyping or improving technical systems. The third category is often qualitative research responding to an issue relating to engineering practice, management and education.

EEE activities in these subjects largely rely on the dynamics of students and academic supervisors. Depending on the types of projects, EEE activities in these project based subjects may appear ad hoc that only focus on micro-ethical issues, such as improving a safety design of a manufacturing process. Research ethics are addressed in the preparation phase as a mandatory ethics screening is required for all student projects. A form is applied to formalise this screening process. Students and supervisors need to identify any potential risks concerning collecting human or animal data, using identifiable data from human participants, intellectual property, etc. This screening activity provides an opportunity for students to make ethical decisions with their own projects.

Student projects focusing on engineering practice, management and education tend to produce fruitful results at the macro-ethical level, especially with respect to SDG attributes. One school of these projects derives from Engineers Without Borders (EWB) projects in which appropriate technologies are introduced or deployed for communities in need of clean water, safe shelter and affordable renewable energy. All these respond to different areas of SDGs such as clean water and sanitation, affordable and clean energy, and responsible construction (UN, 2022). One successful project among these projects was a Southeast Asia residue gasifier project lead by a female engineering student. The student designed and tested – in field – a biomass gasifier for the underdeveloped regions in Southeast Asian countries. In addition to the energy issues she touched upon, this project aimed to enhance sustainability at the community level. Her approach for market analysis responded to the first SDG as to alleviate poverty. The success derives from the student's macro-ethical awareness.

The differences among student performance reflect a gap between engineering ethical awareness. It also reveals a gap of our teaching practices in the sense that bringing students to the macro-ethical level requires a transition. One possible mitigation being taken place in this university at the faculty of engineering and IT is to disseminate marco-ethical awareness in its undergraduate engineering core subjects. In this regard, a review of the engineering core curriculum has been performed. Some new intermedium subjects such as a second or third year humanitarian engineering subject is developed and an existing subject concerning technology and society is being redesigned. The tenet for these teaching reforms is that we as educators do not just care about content and coverage. We also need to think about the level of awareness which has a strong resemblance to engineering ethics.

Analysis and Discussions

Engineering experience accumulates from reflections toward practices. The application of case studies in the teaching of engineering ethics at an early stage of engineering education is useful because case studies of ethical dilemmas serve as collective reflections which bring students into unfamiliar contexts of engineering practice. As such their awareness of the code of ethics becomes substantial. Micro-ethical awareness helps students to define their own engineering projects at the final stage of education. At least, most of the students are able to identify health and safety risks concerning their own projects and to find proper responses to mitigate their impacts. In this regard, the notion that as practical experience accumulates, student's ethical concerns rise gradually to the macro level seems to be plausible.

The observations as such lead to two implications for engineering educators. Firstly, it suggests that engineering ethics is not necessarily to be taught in one subject. It is a source of inspiration for educators to guide students to the broader context of engineering and its application. EEE should be diffused into the curriculum of engineering education especially to professional practice and project based subjects. Secondly, macro-ethical engineering projects should be accepted as decent student projects at the capstone level.

The best approach for EEE is perhaps not to make it a standard subject alone. As ethics for engineering practice can be codified in UN SDGs, its education shall be underpinned by three aspects of comprehensiveness, namely "consilience", "coherence" and "collaboration" (van de Hoven, 2019). In this case, consilience and coherence refers to the fact that micro and macro levels of engineering ethics are two aspects of awareness. These two aspects should be manifested coherently in engineering practice and in teaching and learning activities. EEE can be regarded as a shared vehicle for engineering educators to shape graduates with SDG attributes. In this regard collaboration is necessary.

The observation leads to another implication of the educator's role in engineering ethics education. Due to the flexible nature of the topic, the educator seems to be better acted as an agent that guides students to both the social and technical aspects of the issue. Educators can be regarded as change agents that trigger self-reflection, enhancement of consciousness and motivation of practice that come directly from students.

A remaining question that needs to be discussed in this case is a question on assessment. Whether elements such as ethical awareness or consciousness need to be evaluated? And how? This question also applies to project related subjects. Some academics question that such projects often lack technical depth on which assessors rely to assess student performance. However, such SDG projects with macro-ethical concerns often exemplify advanced project management skills. A trade-off needs to be established in the assessment criteria toward such student projects in that a blanched approach focusing on the project rather than on the technical knowledge might be a direction to be further discussed.

Conclusions

Regardless of approaches and processes, the purpose of engineering ethics education is to create ethical engineers. A narrow focus on micro-ethical issues leads to a procedural approach of the pedagogy of this topic, while macro-ethical issues relating to engineering challenges such as the SDGs serve as sources of inspiration to bring student awareness of engineering ethics to a higher level. Engineering ethics education is better to be diffused into the course of engineering education. Collaborations between early, middle, and final stage educators seem to be essential.

Our intention in this paper has been to make public (Stenhouse, 1981) our concerns about the dominant approach to EEE, and to commence through dialogue an exploration of how we might more skilfully and effectively contribute to the development of ethical engineers. Our approach seems to be appropriately allocated due to the close relationship of engineering ethics with SDGs. The approach is also effective in the sense that combining engineering ethics education at different stages and levels tends to foster students transition from technical specialists to socially responsible engineering professionals.

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