Challenging Students in Teaching Sustainable Engineering – Initiatives in the Technology, Sustainability and Society Course at USQ

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Introduction

The *Technology, Sustainability and Society* course at the University of Southern Queensland teaches engineering and built environment students the knowledge and skills required to meet the sustainability requirements of the Code of Ethics of Engineers Australia (Engineers Australia 2017a). It also addresses engineering competencies in areas like social, cultural, environmental, commercial, legal and political contexts (Engineers Australia 2013). The topics taught in this course (which include the history of technology, sustainability, politics, economics, models of society, cultural impacts, law and management) have accordingly been designed to address the main aspects of sustainable engineering practice and management.

This course is taught to learners in engineering, spatial science and construction undertaking a full degree program, in each of the three teaching semesters of the University. Its learners are normally at Level 1 or Level 2 in their study program. As over 70 per cent of these learners would typically study online, material in this course is delivered in a blended learning format that uses an online Study Desk designed to allow learner interaction with their teaching staff and each other, and to enable them to better understand and apply the principles that they have learnt through engagement with the course material. In order to further develop such engagement, several initiatives have been undertaken that are designed to better engage them in studying this course

While this course has been taught for several years, its acceptance by learners, as measured by student feedback at the end of each teaching semester, has varied. In particular, the importance of its subject matter has not been fully understood by many learners, a number of whom have not seen a clear relationship between their future professional work and a strong focus on sustainable management principles, which may not have an immediate technical application. There has also historically been a mixed degree of engagement by learners with the course and its content, resulting in concerns that a number of learning outcomes were not being achieved. It has therefore been considered important to address these matters, as an understanding of the principles taught in the course at an early stage in the engineering study program provides opportunities for learners to understand their application to practice as they progress with their studies.

Therefore, because of this mixed acceptance of this course by learners, and the desirability to better engage them, considerable effort has been invested over time to improve the content of this course; make it as relevant as possible to engineering and built environment practice; maintain currency with technological developments and the changing environmental, social and political landscape; and encourage the understanding by learners in the course of an increasing worldwide focus on sustainability,

The objective of this paper is to discuss recent developments in this course aimed at improving learner engagement with it, and the way in which these developments have challenged learners and aided their engagement with it.

Sustainability, engineering practice and good teaching

As proposed by Brundtland (1987), sustainable development meets the needs of the present, yet allows future generations to have the ability to meet their needs, a concept that over time has gained government, community and corporate support. In 2015, the United Nations issued the Paris Agreement (United Nations, 2015), which aims to contain increased global temperatures to 2 °C above pre-industrial levels and requires International cooperation to achieve its targets. The Australian government has accepted this agreement, and has committed to reducing carbon emissions by 26 per cent to 28 per cent over 2005 levels by 2030 (Australian Government, 2015). The United Nationals Sustainable Development Goals (united Nations, 2018), which are related to the Paris Agreement, recognise this importance of developing sustainable and resilient communities, and have developed in more detail the traditional sustainability goals of economic development, social equity and environmental protection (Drexhage & Murphy, 2010) into 17 goals, such as availability and sustainable management of water and sanitation; affordable, reliable, sustainable and modern energy; safe, resilient and ecologically friendly cities, protecting ecosystems, and sustainable consumption and production patterns (United Nations, 2018). This approach is likely to govern the future development of sustainable management knowledge and skills.

Professional organisations have developed positions on sustainability. For example, Engineers Australia, as well as including “promote sustainability” as one of the four sets of guidelines on professional conduct in its Code of Ethics (2017a), has published a Sustainability Policy (2014) and guidelines for the principles and practice of implementing sustainability (2017b). In its role description for the mature professional engineer in its Stage 1 competency standard for the professional engineer (Engineers Australia, 2013), this organisation states that professional engineers are responsible for “bringing knowledge to bear from multiple sources to develop solutions to complex problems and issues, for ensuring that technical and non-technical considerations are properly integrated, and for managing risk as well as sustainability.” In the descriptions of the elements of competency in this document, professional engineers are also expected to “consider the interactions between engineering systems and people in the social, cultural, environmental, commercial, legal and political contexts in which they operate” (Engineers Australia, 2013, Section 1.5). Thus, practising engineers are required to not only meet sustainability requirements, but to also professionally interact with wider government, civic and professional communities. This is a significant consideration in developing and delivering a course on technology, sustainability and society.

To gain acceptance by learners, a course that teaches technology, sustainability and society should not only have quality content, but also be delivered according to good teaching principles suited to the practical nature of its content. Examples of such practices include student centred learning, constructive alignment, authentic assessment and experiential learning. Student centred learning is discussed by Biggs (1999), who writes that it is primarily a focus on what the student does, and is based on what it means for students to understand concepts in the way that teachers desire them be understood and the types of teaching and learning activities required for this purpose. This approach is closely linked with constructive alignment, which can be described as a teaching design in which it is stated, before teaching takes place, what learners should learn, and how they should express their learning. Such teaching is designed to engage students in those learning activities that optimises the achievement of learning outcomes. Assessment activities in this approach are accordingly designed to enable clear judgments with respect to the achievement of desired learning outcomes (Biggs, 2014).

A related concept is authentic assessment (Gulikers et al., 2004), which can be linked with student centred learning, and may be viewed as a type of performance assessment that is closely linked to criterion-referenced assessment and alignment with course instruction. In this approach, leaners demonstrate their competencies in a setting that resembles

professional practice, using the dimensions of task, physical context, social context, assessment form and criteria. To this list can be added professional skills, or the skills required by engineer to meet their professional requirements, such as ethics and sustainability (Thorpe, 2013). A further approach to enhancing the learning experience in a practical context is experiential learning (Kolb, 1984), which is primarily aimed at learning from experience, through one or more cycles of concrete experience, reflective observation, abstract conceptualisation and active experimentation, can also be linked with authentic assessment.

In summary, there is an ongoing International commitment to sustainable practices and their development. There is a similar commitment to sustainable practices, including interaction with government, community and the professions by engineering professional organisations like Engineers Australia. Developing the knowledge, skill and understanding of sustainable practices that facilitate interactions with government, society and other professions by engineering and built environment professionals can be best achieved by a teaching approach utilising approaches like student centred learning, constructive alignment, authentic assessment and experiential learning.

Course Objectives and Delivery

The objectives of the *Technology, Sustainability and Society* can be summarised as: comment on general knowledge and current affairs; appreciate the history of technology; understand and apply environmental sustainability; understand and apply the principles of environmental impact assessment; understand the political dimension; understand economics and its role; understand social structures and working in a multicultural environment; understand the legal system and ethical and legal constraints; and understand sustainable management practices and the challenges in managing conflict.

Assessment of this course is by two assignments, each worth 20 per cent of course marks, and an examination at the end of each teaching semester. The course is delivered in on-campus mode at the Springfield and Toowoomba, Queensland, campuses of the University, and online, using the Moodle online learning management system (Moodle, 2019). In 2018, this course had an enrolment of 374 learners, of which 79 per cent studied online. This large proportion of learners studying this course online provides a number of additional challenges in course delivery to that of delivering course content in class, as the opportunity for them to discuss the course and interact with staff and other learners is considerably more limited than in face to face learning. Such issues have tended to compound the mixed acceptance of the course that is discussed in the Introduction to this paper.

Because of the role of this course in the engineering and built environment curriculum in teaching the sustainable engineering and related requirements of Engineers Australia (2013, 2017a, 2017b), it has been considered essential that the course is strongly accepted by its learners and that they engage strongly with the course. Accordingly, a number of initiatives have been undertaken over the past several years to improve the delivery of the course and learner engagement with it, thus leading to improved learning.

Assessment of approach to challenge and engage learners

In order to address the objective of this paper to discuss recent developments in this course, and the way in which these developments have challenged learners and aided their engagement with it, the following approach has been adopted (refer to Figure1):

1. Review the requirements, objectives and delivery of the course.
2. Address the first component of the objective of the paper – discuss initiatives and developments in this course aimed at improving learner engagement with it.
3. Address the second part of the overall objective – discuss the way in which these developments have challenged learners and aided their engagement with it.

4. Briefly reflect on the discussion and develop a conclusion.

Step 1 has been discussed above. The balance of this paper discusses Steps 2, 3 and 4.

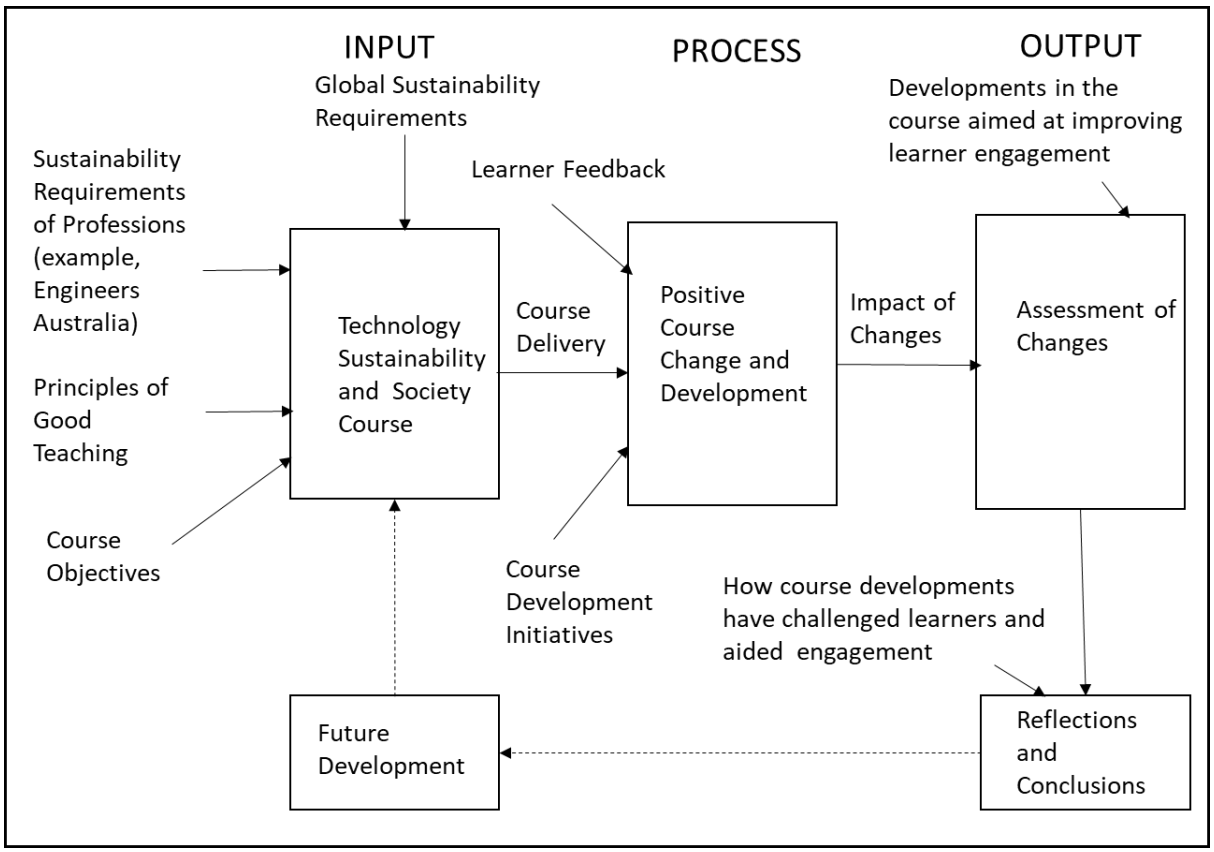

Figure 1: Conceptual Framework – Initiatives in Technology, Sustainability and Society

Discussion of selected developments in the course

Initiatives to improve this course have been undertaken in accordance with both meeting its objectives and the principles of good teaching. While several such principles have been applied, this paper focuses on student centred learning (Biggs, 1999), constructive alignment (Biggs, 2014), authentic assessment (Gulikers et al., 2004) and experiential learning (Kolb, 1984). Selected initiatives undertaken to improve learner engagement with the course, in line with these principles, are discussed below under the three categories of content, delivery and assessment of the course.

Initiatives to improve course content

While engineers and related professionals have recognised and understood the economic and environmental aspects of sustainability, it has been found that the social aspect can be overlooked by engineering learners (Valdes-Vasquez and Klotz, 2011). Therefore, while the *Technology, Sustainability and Society* course addresses most of the aspects of social sustainability, this aspect of the course content has been strengthened through additional content that specifically addresses indigenous Australian aspects in its sections on the history of technology and cultural issues. As part of this process, a guest lecture was delivered by an Australian Aboriginal elder with corporate experience. In addition, part-time International staff have been engaged to assist with delivering course material; and in setting, reviewing and assessing assignments. While further work can be undertaken in the area of cultural aspects of sustainability, and as part of this process better addressing United Nations Sustainable Development goals (United Nations, 2018), the initiatives taken to date in this area have been positive.

Initiatives to improve course delivery

In order to better facilitate interaction with learners who study online, weekly lectures and tutorials delivered on-campus at the Springfield Campus of the University in Semester 1 and Semester 2 are delivered through video conferencing, facilitated by the Zoom Video Communications system (Zoom Video Communications, 2019). These lectures are recorded and are thus available to all learners. This system uses two-way high quality synchronous communications and thus facilitates on-line delivery of course material and responses by learners who cannot physically attend classes either for personal reasons or because they live remotely from the University. This process is further facilitated by the use of part-time staff with industry experience to deliver several of the course lectures and tutorials.

The online Study Desk for the course has also been extensively revised. While it continues to include traditional items like study material, and lecture and tutorial material, it now also includes an engaging introduction to the course. In addition, it now includes a critical thinking exercise that is associated with the material in the particular module of the course that is being taught. Learners are requested to discuss this material and express their views, thus encouraging student centred learning (Biggs, 1999)

Initiatives to improve assessment

There have also been a number of initiatives undertaken to improve assessment, which is focused on current issues. The first assignment focuses on a structured essay on a current sustainability focused topic, from the point of view of key community members, each representing a different point of view. The second assignment, on which learners undertake a sustainability risk assessment, builds on this topic. The examination similarly contains questions on current issues from a sustainability and society viewpoint. These approaches reflect an authentic assessment process (Gulikers et al, 2004), as learners are addressing key issues on real topical questions from an engineering or built environment viewpoint. They also reflect an experiential learning approach (Kolb, 1984), as learners utilise feedback from the first assignment in preparing their second assignment, and feedback from both assignments in preparing for the examination.

The assignments are accompanied by improved marking rubrics that are provided to learners with the requirements of the assignment. A recent innovation has been to allocate a proportion of assignment marks to submissions by learner with respect to their posts on the course Study Desk, which is designed to foster constructive alignment (Biggs, 2014), further enhance an experiential learning approach (Kolb, 1984) and increase learner engagement.

How developments have engaged and challenged learners

The initiatives discussed above have considerably improved the engagement of learners with the course material, and challenged them to critically think and write about the material that is taught. As evidence of increased engagement, it has been possible, through the data analytics capability in the course Study Desk (Moodle, 2019), to obtain detailed and summary statistics that show the number of times that learners have posted to the course Study Desk over each semester. At an aggregate level, the total number of student posts to the Study Desk in the Semester 1, 2018 offer of the course, when there were no marks allocated in the assignments for postings on the Study Desk, was 791. This figure for Semester 1, 2019, when marks were allocated in assignments for such postings, was 2,155, which was a very significant increase. This increase occurred despite a small drop in the number of learners enrolled from 89 in Semester 1, 2018 to 82 in Semester 2, 2019.

There is also evidence of a significant improvement in the evaluation scores given by learners for the course and its teaching evaluations at the end of each semester (Figure 2) over the period from Semester 1 2016 to Semester 1 2019. Course evaluation in Semester 1 2016 was rated at 3.26 on a scale of zero to five, and had decreased to 2.74 (considered to

be within the variation limits for this type of response) for the online only delivery in Semester 3, 2016. With the subsequent ongoing development of initiatives in the course, the student evaluation score for Semester 1 2019 had increased to 4.00 on the same scale, or an increase in this score of 0.74 points over that of Semester 1 2016. A similar pattern has occurred for the evaluation of teaching over the same period. These evaluations, which can be considered as an indicator of the way in which the course content and delivery meet the requirements and interests expected from the course by learners, are shown in Figure 2. The linear trend lines in Figure 2 for each of these evaluations have a positive upward slope, thus showing an overall improvement in both of these measures over time.

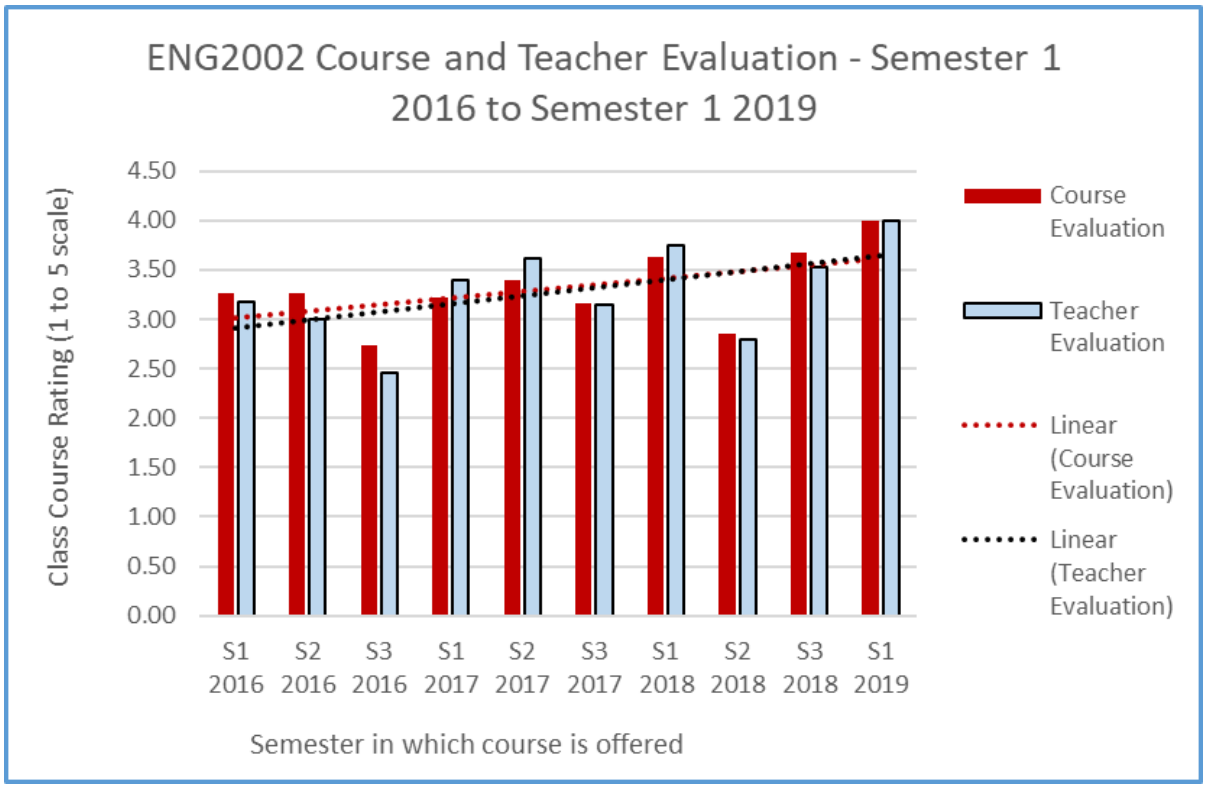

Figure 2: Learner Evaluations of Course and its Teaching

Reflections and Conclusions

On reflection, the overall positive trend in the numbers of learners engaging with this course, and the positive trend in course and teacher evaluation in it over the period from Semester 1 2016 to Semester 1 2019 demonstrates that learners are increasing their engagement with it and seeing it positively. It would therefore be expected that the learning from study of this course would have correspondingly increased over time. Therefore, as result of the implementation of the positive change initiatives in the course, it is expected that future engineers and built environment professionals studying the course are likely to have a strong focus on the impact of their professional practice on the environment and their projects.

Further development in the course is possible through continual improvement in the teaching material, the ways that the teaching material is delivered, further development of assessment, and continuing to enhance the role of the student in the learning process. Such initiatives are expected to be undertaken in the future. This process will also be influenced by future global developments, such as how well the recommendations of global agreements like the Paris Agreement (2015) are implemented. For these reasons, additional topics, like recycling, increased use of sustainable energy, a potentially stronger focus on the United Nations Sustainable Development Goals (2018), technological advances and a changing cultural and political landscape may impact on community expectations of engineers and

built environment professionals. Such changes are likely to significantly impact on the work of these professionals, and the way in which professional knowledge and skills are taught.

A first task in this process is likely to be a review of the material taught in this course. A related task could be to improve how this course is scaffolded to develop principles that build on each other and form a ladder to future courses in a sequence. As these developments occur, there are likely to be changes in the way that the course material is taught and assessed, in line with the principles of good teaching.

In conclusion, the initiatives that have been put in place to develop the Technology, Sustainability and Society course have to date been successful in engaging and challenging learners. Further course developments are expected to maintain this momentum.

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