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Integrating sustainable development into a first-year project-based learning engineering course

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ABSTRACT

CONTEXT

The Washington Accord graduate attributes have recently been revised and they now place more emphasis on designing creative solutions which address sustainable development. This includes resource use, whole of life cost, impacts and other holistic considerations. This suits a project-based learning style which allows students to explore a problem and propose potential solutions.

PURPOSE

A first-year project-based learning course was developed and first delivered in 2020. The course has two goals: development of skills and development of knowledge. In this course the skills are key problem-solving tools. The knowledge focuses on sustainable development (including the UN Sustainable Development Goals) and cultural considerations. The team project gives opportunities to apply the problem-solving skills, and the context of the project addresses sustainable development, including social/cultural aspects. The purpose of this paper is to review the first two offerings and approach to integrating sustainable development into this course.

APPROACH

This paper describes the strategies used when designing and delivering this course over two years. A particular area of focus is on how well sustainable development was integrated into the course and the management of the projects using a Stage Gate approach.

OUTCOMES

For the first offering the project was focused on a product, and this meant when considering the life cycle the scope was very wide and the students needed to gain an understanding of what was happening globally. It was felt that a narrower scope was needed for first year students so in the second offering the project was changed to a New Zealand industry. This scope was more manageable, and it allowed much stronger links with te ao Māori (Māori world view) and Mātauranga Māori (Māori knowledge) which are also important aspects of the course.

CONCLUSIONS

Narrowing the scope and making the focus within Aotearoa New Zealand allowed the students to gain a better understanding of the life cycle and make more meaningful links with te ao Māori. Using a Stage Gate approach to managing the projects worked effectively for both students and staff.

KEYWORDS

Project-based learning, sustainability, Sustainable Development Goals

Introduction

Sustainability has been identified as a key area for curriculum development across many fields (for example Redding and Cato, 2011; Ebaid, 2021). Engineering graduates in particular, will be developing future solutions but they need to develop their knowledge and problem-solving skills in this area. Therefore, programmes need to place more emphasis on updating the curriculum to facilitate graduates of the future to drive change.

The United Nations Sustainable Development Goals (UNSDGs) which were adopted by all United Nations Member States in 2015 provide 17 goals which incorporate the different dimensions of sustainable development – social, environmental and economic. Each of the goals then contains specific targets. In fact Goal 4 Quality Education has a target which specifically addresses the need for knowledge and skills to promote sustainable development:

> *"By 2030, ensure that all learners acquire the knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship and appreciation of cultural diversity and of culture's contribution to sustainable development" (United Nations, n.d.)*

The importance of sustainable development has been highlighted in the updated International Engineering Alliance graduate attributes and professional competencies (International Engineering Alliance, 2021). The updated graduate attributes at Washington Accord level highlight the need for "holistic considerations for sustainable development" and the need to "analyse and evaluate sustainable development impacts" represented by the 17 UN Sustainable Development Goals. Additional emphasis has also been placed on the need for "critical thinking in the broadest context of technological change". Other papers have reported on the importance of the integration of sustainable development into engineering programmes, for example, in Europe (Leifler and Dahlin, 2020) and China (Qu et al., 2020).

Sustainable development can be complex and problems that graduates face in the future may not have an obvious solution. It is also difficult to predict what the challenges of the future will be. Therefore, students need to develop general problem-solving skills rather than learn about solutions to well defined problems (Leifler and Dahlin, 2020).

The need for knowledge and skills development as well as problem solving skills, means that a project-based learning approach has been previously proposed (Nation, 2008; Cörvers, et al. 2016). This paper describes the development of a first-year engineering project-based learning course which has a focus on sustainable development and changes made after the first offering. The focus is on how well sustainable development was integrated into the course and any changes in attitude reported in the reflective reports.

Context

Massey University has a series of project-based learning courses throughout the Engineering and Food Technology programmes. Students complete one project-based learning course each semester. In 2020 all first-year courses were reviewed including the project-based learning courses. The previous first year project-based learning courses focussed on written and visual communication, an introduction to project management, teamwork, and creative thinking.

During the review of the first-year courses the need to introduce sustainable development was identified along with a need to ensure students start to learn more about te ao Māori (Māori world view) and mātauranga Māori (Māori knowledge). There are strong links between this cultural knowledge and sustainability.

A new first year second semester course was developed called 247.114 Science and Sustainability for Enigneering and Technology. This is one of four courses within the College of Sciences which are designed for different disciplines but share some common content. The Engineering and Technology offering differs from the other offerings in that it is a project-based learning course.

The Course prescription is: A project-based, interdisciplinary course introducing students to the applied scientific thinking and theories that underpin the relationship between applied science and sustainability. An exploration of how the Treaty of Waitangi underpins a partnership between Pākehā and Māori, focussing on ways in which Applied Science can be guided by Tikanga Māori (including culture, ethics and knowledge systems). By examining the interactions between human, cultural, environmental and technological systems, students will develop their critical thinking, communication and literacy skills as they develop solutions to contemporary challenges in sustainability in a team-based project.

The learning outcomes for the course are:

1. Critically appraise information.
2. Use scientific information to communicate issues of sustainability to a range of audiences.
3. Discuss the impact of mātauranga Māori for advancing sustainability.
4. Work collaboratively to explore society- through to individual-level solutions to sustainability challenges.
5. Reflect on the concept of sustainability.

There are two key areas of focus in the project-based learning courses – development of knowledge and development of skills. For this course in terms of knowledge the focus is on introducing sustainable development (including the UN Sustainable Development Goals) and providing a strong foundation of knowledge so that cultural considerations can be taken into account within their project. The skills being developed are information finding and evaluation, communication to different audiences, working in teams, and reflective practice. The approach to reflective practice developed for this course has previously been reported in Brown (2022).

Course Development

Overall plan for the course

To help guide the students throughout the project the Stage Gate approach was used. The project was split into three stages. In order to progress to the next stage, teams had Gate Meetings with a panel of staff to show that they had completed all the necessary tasks for that Stage. Stage 1 involved information finding and evaluation of their information sources. Stage 2 focussed on generating ideas and screening them. Stage 3 then allowed each student to evaluate one of their ideas in detail. A summary of the knowledge, skills and Gate meetings are shown in Figure 1 and further explanation of each Stage is provided below.

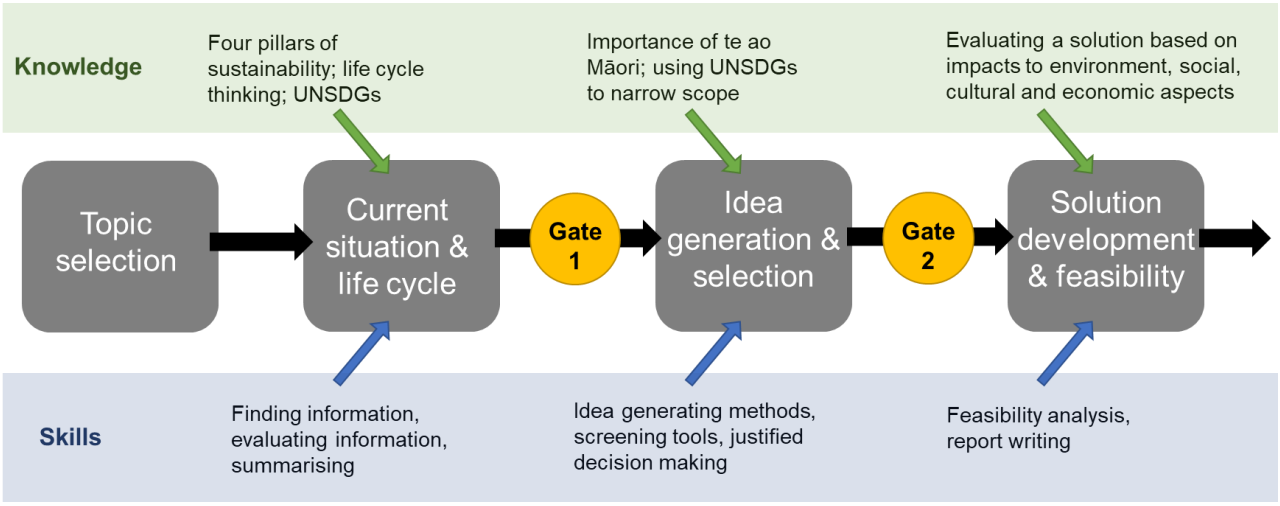

Figure 1: Strategy to incorporate key areas of knowledge and skills into the project

Stage 1

Students are placed into teams of four and they select their topic for the project from a list. The topics are discussed in the next section. The teams then need to build up their understanding of their topic. To do this they require some basic understanding of what sustainability is, life cycle thinking and the UNSDGs. With some background information on these topics they then set out to understand what the current situation is and what the life cycle of their product/industry is. The enabling skills at this point are finding information, evaluating information and summarising. As a group students then attend their first Gate Meeting where they need to show:

- A life cycle diagram showing raw extraction, manufacturing, transport, use and end of life. This is backed up by research
- A SIPOC diagram showing the suppliers, inputs, processes, outputs and customers
- Project planning out until the next Gate Meeting

Individually the students also submit a written assessment where they summarise 3-4 sources of information into a few paragraphs along with an evaluation of one information source using the CRAAP (credibility, relevance, authority, accuracy, purpose) framework. This individual assessment is to ensure that each team member is contributing.

Stage 2

Once the students understand the entire life cycle they then appreciate that they need to prioritise areas to focus on as it would be too complex to develop solutions for the entire life cycle. The students map the SDGs onto different areas of the life cycle and use their knowledge from the first Stage to narrow the scope for the rest of the project. Each team can select one or two areas of the life cycle to focus on. These tended to be raw extraction, manufacturing or end of life.

At the same time as they are narrowing their focus, they are also learning about te ao Māori (Māori world view) and mātauranga Māori (Māori knowledge). Their understanding is assessed individually in a written assessment. The students select one of 5 companies who use te ao Māori principles in their business and propose how similar principles could be adopted in their industry.

Once they have narrowed their scope students are then given a range of idea generation methods and a wide range of creative ideas are developed for the part(s) of the life cycle they are focussing on. Different techniques are also introduced to help the students screen their ideas. Most teams use multiple methods. For example, a pass/fail screen followed by a weighted matrix. For the second Gate Meeting the students need to be towards the end of their screening process. The second Gate Meeting focusses on making sure that they can justify the decisions they have made rather than just selecting ideas that they think are interesting.

Stage 3

In the final stage each individual took one proposed solution to investigate in more detail. They developed the idea and considered its environmental, social, cultural and economic impacts. Students also looked for any unintended consequences by referring back to the life cycle they had developed and thinking about what the impact would be if their solution was implemented. Students also commented on the technical feasibility of the solution although sometimes their analysis was simple due to their limited technical knowledge. Finally, a recommendation was given as to whether the industry should continue to investigate the solution or not. This recommendation needed to be supported by their analysis.

Assessment was via a written technical report. The assessment focused on the analysis and a logical recommendation rather than on the idea itself. This meant that even if the idea was not going to work the students were not penalised in their assessment.

The student projects

For the first offering of the course the student projects were centred around consumer products and each group focused on a different component/ingredient. Examples are shown below:

- Chemical and Bioprocess Engineering students focussed on a takeaway cup of coffee.
    - Groups then chose one component: coffee beans, milk, water, disposable cup
- Mechatronics students focused on a toaster
    - Groups then chose components such as the outer casing, the elements, mica plate, cable, packaging, metal frame
- Food Technology students focused on a block of chocolate
    - Groups then chose ingredients such as sugar, cocoa, soy lecithin, packaging

Course Evaluation and Development

Evaluation of first offering

After the first offering of the course staff identified that while the content and flow of the course worked very well, the projects which the students worked on could be improved. The key element which students struggled to relate to their project was the cultural considerations. While the students learnt about te ao Māori (Māori world view) and mātauranga Māori (Māori knowledge) the students didn’t get an opportunity to apply this knowledge to the project because often the sustainability issues identified were in an international context rather than within Aotearoa New Zealand.

Some students also struggled to understand what was happening internationally. Developing a solution for another area of the world which they were not familiar with was challenging. Students often realised that the solutions which were needed were not always technical ones.

The solutions developed by the students covered a wide range of topics and addressed several different SDGs. The most common SDGs focussed on were:

- SDG 8: Decent work and economic growth
- SDG 9: Industry, innovation and infrastructure
- SDG 12: Responsible consumption and production
- SDG 13: Climate action
- SDG 14: Life below water
- SDG 15: Life on land

The Stage Gate system worked very effectively and provided a clear path for the students to follow. There were a few teams which failed their first Gate meeting but they were given feedback and were able to show they had completed all their tasks by the following week. The mapping of the knowledge and the enabling skills across the course was very effective.

The student reflections at the end of the course agreed with staff observations. The students tended to report that they had a broad understanding of sustainable development however, the importance of cultural considerations tended to be lacking.

New project focus for second offering

To ensure the students were given an opportunity to apply their knowledge of te ao Māori and mātauranga Māori the projects were set within Aotearoa New Zealand. In 2021 groups were given the choice of different industries and their task was to propose ways for these industries to become more sustainable within Aotearoa New Zealand. Many of the larger industries such as dairy and beef already have sustainability plans so smaller industries were selected. Examples include salmon, seaweed, wine, timber, avocados, domestic construction, industrial construction, and peanut butter.

There were no changes made to the way the course was taught or how the project teams were managed. This means that changes between the two offerings are likely to be due to changes in the topics for the projects.

Having the projects focused on industries within Aotearoa New Zealand made the integration of sustainable development and cultural considerations within the project much stronger and more obvious to the students. It also helped the students to relate to the projects because they were on their 'backdoor' rather than within an international context which some students struggled to relate to within the first offering. While having an international understanding of sustainable development is important, it was felt that for this first year course when they are still developing their basic knowledge and skills, having a simpler project they could relate to was advantageous.

Within the student reflective reports there was far more focus on how important te ao Māori is for sustainable development within Aotearoa New Zealand. In the first offering this was hardly mentioned in the reflective reports but it was very common after the second offering.

Conclusions

A first-year project-based learning course was successfully developed which enabled students to appreciate the importance of sustainable development. For the first offering the projects focused on a consumer product. The students found it difficult to propose sustainable solutions within an international context and did not get as many opportunities to apply their knowledge of te ao Māori. For the second offering industries within Aotearoa New Zealand were selected and this was much more successful.

The Stage Gate approach was very useful to help guide the students as there were key tasks which needed to be completed with scheduled Gate Meetings to check on progress. Mapping key areas of knowledge development and enabling skills for each Stage helped staff ensure that students had all the tools needed to complete their project.

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