Implementing a holistic process for embedding sustainability: a case study in first year engineering, Monash University, Australia

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Abstract:

While there is clear recognition of the need to incorporate sustainable development into university curricula there is limited research that examines how to achieve that integration or evaluates its impacts on student learning. This paper responds to these knowledge gaps by examining a case study of curriculum renewal that involved embedding sustainability into the first year engineering curriculum at Monash University, Australia. The initiative was guided by a deliberative and dynamic model for curriculum renewal that engaged internal and external stakeholders through a structured sequence of facilitated workshops and meetings. That process identified sustainability-related knowledge and skills relevant for first year engineering, and faculty were guided through a process of curriculum renewal to meet those needs. The process through which the whole of curriculum renewal was undertaken is innovative and provides a case study of precedent in the field of education for sustainability. The process maintained engagement with external stakeholders and academic staff. The study also demonstrates the contribution that can be made by a web-based sustainability portal in supporting curriculum renewal. Learning and teaching outcomes were evaluated through 'before and after surveys' of the first year engineering students. Statistically significant increases in student's self-reported knowledge of sustainability were measured as a result of exposure to the renewed first year curriculum. While applied in this case to engineering, the approach is likely to have value for other academic disciplines both in terms of the process to achieve integration of sustainability into the curriculum as well as in seeking to evaluate its impacts on student learning.

Keywords: sustainability curriculum renewal; collaborative stakeholder engagement; learning outcomes; virtual learning environment; evaluation

Article Classification: Educational Initiatives

1. Introduction

Redressing the imbalance in environmental, social and economic outcomes that characterise contemporary, unsustainable, societal systems presents a formidable challenge and one in which education plays a central role. The importance of education in this context was recognised by the United Nations in their declaration of the Decade for Education for Sustainable Development (DESD) (2005-2014). As the DESD draws to a close, assessments are emerging that Higher Education Institutions are changing teaching, learning and research in ways that can contribute to sustainable living. However, the strongest engagement with Education for Sustainable Development (ESD) tends to be by universities focussed on teaching, rather than those which are research intensive (Wals, 2014). A range of substantial barriers exist to realising sustained ESD in universities, spanning budget and resourcing, cultural inertia, and champion-based efforts that are susceptible to institutional disruption (Holmberg and Samuelsson, 2005; Desha and Hargroves, 2009; Lozano, 2010). However maintaining pre-existing approaches exposes institutions to risks associated with tightened legislation and regulation, increased accreditation requirements and shifts in industry demands of graduate capabilities (Desha et al, 2009). As noted by Watson et al (2013, pp 107) “In spite of the recognized need to incorporate SD into curricula, change has been little and slow, and there is still limited research explaining the incorporation of sustainable development into university curricula”.

Engineering has long been recognised as a key discipline, obliged to contribute to a sustainable future (Velazquez et al, 1999; Davidson et al, 2010; Karatzoglou, 2013). Yet a number of international reviews and assessments have found engineering students’ knowledge and understanding of sustainable development to be lacking (Ashford, 2004; Azapagic et al, 2005; Byrne et al, 2013) and there is growing global concern with the lack of sustainability content in engineering curriculum (Desha and Hargroves, 2009). There has been a plethora of articles over the last decade in particular, documenting and in some cases evaluating, individual and institutional efforts in curriculum renewal ranging from initiatives targeting an individual course (Lundholm, 2004) or whole programs (Svanstrom et al, 2012) to design of entirely new degrees (Lozano and Lozano, 2014). Part of the challenge is that there are substantial time lags in curriculum renewal. Traditional curriculum renewal can take 15 to 20 years (three to four program accreditation cycles) and consequently rapid curriculum renewal approaches need development and testing (Desha et al, 2009). This presents an opportunity for organisational learning in the long term-transformation of individual, professional and organisational norms and practices towards sustainability (Jha-Takur et al., 2009).

Australia is in a strong position to advance sustainability in the context of engineering education because of the role of Engineers Australia (EA) as the professional accreditation body for engineering in Australia. EA’s strong commitment to sustainability, is reflected in the

Stage 1 competency requirements (Engineers Australia, undated) that underpin engineering course accreditation. This clarity of expectation highlights the need for Australian institutions to address quite explicit sustainability related graduate attributes, and embed these within the undergraduate experience.

This paper presents a case study of an initiative to develop and trial a holistic approach for integrating sustainability into the engineering curriculum at Monash University in Melbourne, Australia. While Monash is a young institution (it admitted its first students in 1958) it has developed to be Australia's largest research-intensive university (ranked in the top one per cent of world universities and 91st in the world according to the Times Higher Education World University Rankings 2013-14). As a research-intensive university, Monash represents an important case in the context of advancing ESD given that research-intensive universities have had less engagement with ESD to date (Wals, 2014). Annually, Monash University contributes approximately 6 % of all engineering graduates in Australia and 15 % of engineering graduates from research-intensive universities in Australia.

Supported by a grant from Sustainability Victoria, Monash University undertook an initiative to embed sustainability in the first year of the Bachelor of Engineering program. Since the Bachelor of Engineering begins with a combined first year, it is an ideal entry point to maximise the reach and impact of integrating sustainability into the curriculum. The aims of this paper are to examine the process of curriculum renewal to embed sustainability and evaluate its impact on learning outcomes.

The paper begins by reviewing insight from the literature on the integration of sustainability in curricula. The following section introduces the model which guided the curriculum renewal initiative, detailing the approach that underpinned the design and implementation of the initiative, including key outcomes. Attention then turns to results from student surveys conducted before and after exposure to the renewed curriculum. Those surveys were used to measure changes in student's knowledge of sustainability and their perceptions of its importance. The discussion section places the results into perspective against existing knowledge while the final section presents the conclusions and identifies research directions.

2. Integrating sustainability in the curriculum: Insight from the literature

This section addresses three key questions:

- How is sustainability integrated into curricula?
- What are the differences in terms of education design (learning outcomes, curriculum, pedagogy and assurance of learning)?
- What does it achieve?

In addressing the first of those questions there are two dimensions of ‘How’ which are relevant: ‘How’ in terms of different approaches to incorporating sustainability into the curriculum; and ‘How’ in terms of the process employed to undertake the curriculum renewal.

A range of approaches have been identified for how sustainability can be integrated into the curriculum. Strategic options can be distinguished based on whether they emphasise vertical or horizontal integration (Watson et al, 2013). Vertical integration involves adding a specific sustainability course to the curriculum whereas horizontal integration can range from providing some coverage of sustainability issues in an existing course, intertwining sustainability in existing courses, offering a sustainability specialisation within an existing program or designing a specialist sustainability degree. The risk with vertical integration is that it may not provide an adequate counter to ‘unsustainability’ which may be reflected in other courses in the program or that the isolated nature of the sustainability content will not enable students to incorporate it into their professional practice (Peet et al, 2004).

In terms of the process of curriculum change there is limited insight in the literature. Desha and Hargroves (2011; 2014) developed a dynamic and deliberative model for embedding sustainability in university education systems, which addresses the need for a multi-faceted, systemic approach. Their model draws on curriculum renewal theory, case study literature and more than 70 colleagues’ curriculum renewal experiences in Australia and overseas. While the Desha and Hargroves’ model emphasizes both internal and external collaboration, many of the initiatives described in the literature have an internal focus with faculty members being the prime contributors to curriculum renewal (Hyde and Karney, 2001; Fenner et al, 2005; Biswas, 2011). That internal focus is also inherent in the individual interaction method employed at a number of European Universities to embed sustainability in the curriculum (Holmberg et al, 2008)

While the process of curriculum renewal is rarely explicitly described, the literature does highlight a range of tools including concept maps and syllabus benchmarking tools which have been employed to support curriculum renewal to integrate sustainability. Concept maps can help to map the underlying structure and complexity of concepts related to sustainability (Lozano and Lozano, 2014). STAUNCH is one syllabus benchmarking tool, which rates the extent to which social, environmental and economic and cross cutting themes are addressed in course descriptors or syllabi, (Watson et al, 2013; Lozano and Lozano, 2014).

A number of differences emerge in terms of education design (learning outcomes, curriculum, pedagogy and assurance of learning) when sustainability is incorporated into the curriculum. An emerging area of the literature focuses on articulating sustainability competencies (Wiek et al, 2011), which have a potentially valuable role to play in framing learning outcomes and therefore influencing the design of the curriculum and pedagogy. While learning outcomes are occasionally mentioned explicitly (Biswas, 2012) there often

appears to be an emphasis on content rather than explicit articulation of learning outcomes (e.g. Watson et al, 2013; Lozano and Lozano, 2014) and concerns that the content often emphasises the environmental dimension of sustainability at the expense of the social and economic dimensions (Watson et al, 2013). It is not uncommon for curriculum renewal effort to involve new modules (Paten et al, 2005; Schneiderman and Friihoefer, 2012) while from a pedagogical perspective there may be the addition of case studies (Biswas, 2012) or simulation games (Lourdel et al, 2005). Segalas et al (2010) examine the effectiveness of different pedagogical approaches in enhancing student's sustainability knowledge and they identified active learning pedagogies, including problem based learning, role plays and case studies, as being more effective in enhancing student's sustainability knowledge. The literature provides little examination of assurance of learning in the context of assessment although group projects have been explicitly identified as being employed to assess multidisciplinary teamwork skills (Biswas, 2011).

Finally we consider the issue of what does integration of sustainability into the curriculum achieve. One key issue is what outcomes are measured. In some cases it is only student satisfaction which is measured following a sustainability related curriculum renewal initiative (Biswas, 2011). While potentially important, student satisfaction is hardly a useful indicator of learning outcomes. Concept maps have been employed to obtain a rich picture of student understanding of sustainability concepts and their interrelationship. Lourdel et al (2007) used conceptual maps and counted the number of times engineering students used words in certain categories as part of their maps. They report results which show an increase in the number of words associated with the three key dimensions of sustainability (economic, environmental and social) following a change in the curriculum to integrate sustainability but they did not subject the results to statistical testing. More recent research (Segalas et al, 2008, 2010) has extended the insight obtained using conceptual maps to include not only the dimensions of sustainability which they reflect (covering economic, environmental, social and institutional aspects) but also the complexity of the interconnections which are represented. Some studies measure changes in attitudes using variants of the New Ecological Paradigm (NEP) (Schneiderman and Friihoefer, 2012). Focussing solely on attitude is problematic since it is known to be a poor predictor of behaviour in the context of education for sustainable development (Arbuthnott, 2009). Ecological footprints have been used as an outcome measure with Ryu and Brody (2006) finding statistically significant changes in student behaviour (as measured by their ecological footprints) after being exposed to a curriculum that emphasised sustainability. Boon (2011) assessed students' sustainability beliefs and knowledge although again the link to behaviour in a professional context, and how that behaviour would change as a result of integrating sustainability into the curriculum, is missing.

Regardless of the outcome measures used, there is also the broader issue of the experimental design employed in the study. Before and after assessments have been employed (Lourdel at al, 2007; Selagas et al 2008, 2010) although usually with a treatment only group which were exposed to the sustainability enhanced curriculum. It is less common for studies to employ a more rigorous experimental design with inclusion of a control group. Hyde and Karney (2001) used a survey instrument based on the NEP to test not only the engineering students who had been 'treated' with their curriculum change, but also a history class where sustainability was not integrated in the curriculum. Likewise Ryu and Broady (2006) included treatment and control groups in their study which found positive changes in the ecological footprints when students a graduate course on sustainable development. In those cases the combination of before and after measurements on treatment and control groups strengthens the conclusions that can be drawn from the evaluation results.

To summarise, the literature contains limited insight into the process by which curriculum renewal to integrate sustainability is undertaken, suggests that curriculum changes to date have largely been framed in terms of changes to content with little consideration of desired learning outcomes, and offers limited examples where rigorous testing has been able to conform that changes in learning outcomes have taken place as a result of curriculum change. The initiative described in the sections which follow provides contributions in each of those areas.

3. Implementing a holistic process for curriculum renewal

In the context of frameworks which have previously been proposed for integrating sustainability into higher education (Rusinko, 2009) this project takes a discipline specific focus but targets a whole of curriculum structure, i.e. horizontal integration. While not explicitly considered in the original design of the approach, this initiative effectively evolved into an action research project promoting change through organisational learning and development (Benn and Dunphy, 2009).

The dynamic and deliberative model of curriculum renewal developed by Desha and Hargroves (2011; 2014) (Figure 1) was used as scaffolding for the process. Applying the model to the Monash University project, the team developed a process comprising four major collaborative events, including two workshops and two meetings as summarised in Table 1. The workshops were facilitated by Dr Cheryl Desha and Mr Charlie Hargroves from The Natural Edge Project, in the capacity of external consultants to the University. The collaboration was considered beneficial, not only for its value-adding within the funding application, but also for the objectivity and subject-area expertise that could be provided to the internal research team members.

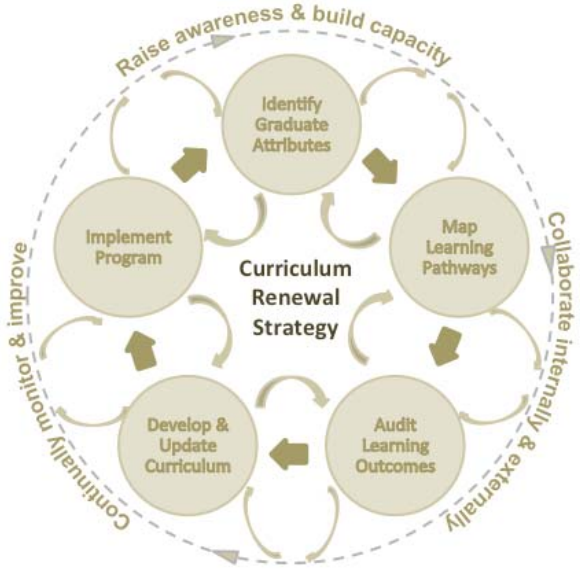

Figure 1: Dynamic and deliberative model for curriculum renewal
(Source: Desha and Hargroves, 2011)

As highlighted in Table 1, the first workshop included practising engineers and representatives from the Engineers Australia Accreditation Panel in addition to academic staff and the external project consultants. Those external representatives helped identify graduate engineer competency gaps relating to sustainability. The workshop participants then grouped those competency gaps into thematic areas and prioritised them for attention in the first year of an engineering degree. This was an important contribution of the first workshop, combining the identification of graduate attributes and the mapping of learning pathways following the model shown in Figure 1. The final set of competency gaps were grouped into four priority thematic areas:

Table 1. Summary of strategic initiatives for curriculum renewal

	Workshop 1: Vision, competencies & learning outcomes	Meeting 1: Existing curriculum review	Workshop 2: Curriculum design	Meeting 2: Finalising Implementation
Aims	To develop a vision for first year that embeds sustainability; and to develop sustainability learning outcomes for first year	To review the curriculum for coverage of the desired sustainability learning outcomes	To review learning outcome mapping; align content & assessment to achieve sustainability learning outcomes	To provide an opportunity for fine tuning prior to the launch of the initiative
Duration	6 hours	2 hours	6 hours	2 hours + one-on-one sessions
Participants	*(12):* Potential employers in key program disciplines, Engineers Australia (peak professional association and accreditation agency), Students, and Faculty (lecturers)	*(8):* First year lecturers, program director	*(12):* First year lecturers, program director	*(12):* First year lecturers, program director
Outcomes	• Sustainability nominated as a key integrating theme for educating engineering students • Desired competencies (graduate attributes) identified by stakeholders, and grouped into four priority themes: 1) Sustainability and its relevance to engineering; 2) Thinking dispositions (reflecting systems thinking, life cycle analysis and critical thinking); 3) Natural systems; and 4) Personal and professional attributes (primarily related to communication skills). • A set of 3-5 specific learning outcomes were established for each theme, mapped to the first year program	• Identified a number of existing learning outcomes that address desired sustainability related learning outcomes • Identified a number of opportunities to formalise existing lecturer efforts to integrate sustainability through explicit learning outcomes • Identified additional sustainability learning outcomes to be added to a number of the units.	• Review of proposed sustainability-related learning outcomes and opportunities within their unit • Connection of each of the learning outcomes to content and assessment • Group discussion of broader implications for the structure of the first year program • Development of a draft implementation plan including tasks and timelines	• Reviewed the content and status of the web portal developed to underpin the initiative • Followed by one-on-one discussions with each unit lecturer to assist with finalising detailed plans on how the sustainability elements would be embedded in each of the units. • Discussions summarised in a curriculum map that identified where each of the components of the portal would be linked to lectures, tutorials etc., and assessment in each unit.

1. Sustainability and its relevance to engineering;
2. Thinking dispositions (systems thinking, life cycle analysis & critical thinking);
3. Natural systems; and
4. Personal and professional attributes (primarily related to communication skills).

For each of those thematic areas, appropriate learning outcomes at a first year level were subsequently developed. Those learning outcomes reflected achievable foundations that could be laid in the first year program in the development of each competency.

The study approach was designed to incorporate effective internal and external collaboration as highlighted by the outer circle in Figure 1. Following the initial workshop (identifying the learning outcomes) the following three events focussed on academic staff teaching in the first year program (see details in Table 1). Those subsequent interactions audited the existing learning outcomes against the sustainability ones developed in the first workshop (Meeting 1), developed an approach to deliver the new learning outcomes (Workshop 2) and finalised implementation details (Meeting 2). There remains scope for the initiative to evolve through continuous monitoring and improvement, raising awareness and building staff capacity.

4. Subsequent curriculum innovations

The process highlighted that while there was some current content related to the sustainability learning outcomes, in many instances it was somewhat superficial (except in one unit[1]). Consequently there was scope to strengthen the content and assessment to achieve deeper learning outcomes in the four sustainability themes than was currently the case. The process also highlighted the desirability for a core unit for all students which would serve as a 'flagship' on sustainability, supported by an 'armada' (Desha and Hargroves, 2011; 2014) of other units which would reinforce the sustainability theme across the different areas of engineering practice. This discussion raised issues related to course design since the existing structure means that not everyone does the flagship unit nor do they complete units in the same order and so it is not possible to rely on content already being covered in a preceding unit.

Options for the development of common content were explored and considered in the development of the implementation plan. Expanding on the naval analogy, this amounted to the development of a 'supply' ship, which was to take the form of a web-based portal, where core sustainability material would be provided. Students were to be directed to that common resource material, to be designed to cover the key learning outcomes areas, and thereby

[1] Students enroll in 'units' at Monash University. In the US this would be referred to as a 'class', in other countries would be a 'paper' (New Zealand) or a 'course'.

obviate the need for each first year lecturer to cover the same material relating to sustainability in their lectures. Instead the lectures would build on the material provided in the portal by drawing links of relevance to the content of individual units. Staff would use the web-based portal as a resource for case studies, general lectures and current sustainability articles. This is important as it removes the necessity for each academic to source their own material in a space with which they are not familiar.

An implementation plan was developed to ensure that the renewed units could be rolled out for the beginning of the next academic year in 2012. Given the lead time and available resources, in consultation with stakeholders the research team decided to focus on the sustainability learning outcomes related to ‘Sustainability and its relevance to engineering’ and ‘Thinking Dispositions’ as priorities for implementation in 2012.

A key element of the implementation was the development of common resource material to be made available to all first year engineering students via the web-portal. Web portals have been shown to have a valuable role to play in supporting learning (Carlson, 2002; Farmer, 2003). Common resource material was developed and structured to highlight essential content and also to provide links to extra material for students who are particularly motivated and wish to explore the sustainability learning areas in greater depth. The intent was that individual unit lecturers could then build on that core content and explore its application in the discipline areas that they cover in their units.

The web portal, illustrated conceptually in Figure 2, was developed around four content areas which reflected the learning outcomes areas identified in the first workshop. Each component contained short webcast lectures on the topic, links to additional resources, activities related to each theme and a range of on-line discussions where students could consider applications of the material provided on the site. A newspaper panel was also included which contained links to current on-line articles that relate to sustainability in engineering.

First year unit lecturers could direct the students to the web portal for revision as background to a lecture, in-class discussion or assignment. This approach meant that every staff member did not have to introduce new lectures on sustainability. Staff could then explore the discipline specific application of key generic sustainability topics. In some instances students were directed to the web portal to obtain background information they needed in order to complete assignments.

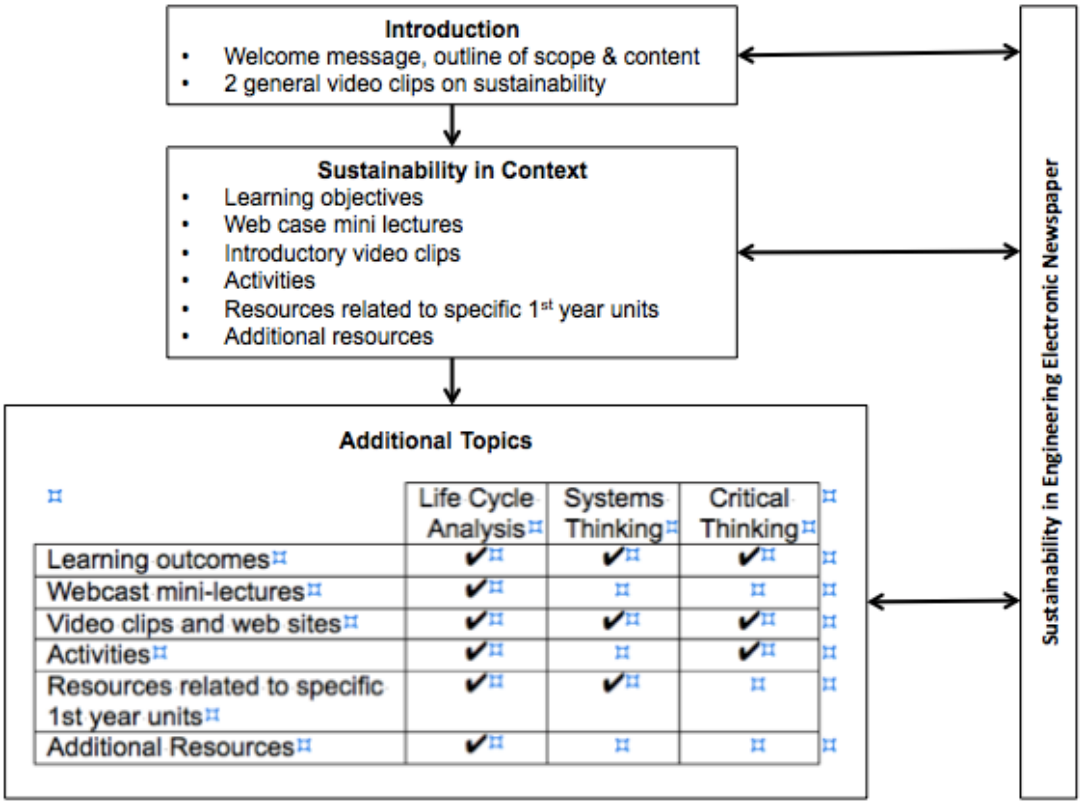

Figure 2. Conceptual structure of web portal design

5. Evaluating the success of the initiative through student surveys

As noted earlier, a variety of approaches have been used in the literature to assess the impact of curriculum changes relating to sustainability including concept maps and questionnaires. Given that the process was guided by the learning objectives established in the first workshop a decision was made to focus on measuring the impact on student comprehension using a questionnaire. This approach was also considered appropriate given the resources available for this initiative and the large cohort of first year engineers (nearly 1,000 students) and the efficiencies associated with undertaking the evaluation using an on-line questionnaire as opposed to analysis of individual concept maps.

Following an approach previously reported in the literature (Azapagic et al, 2005; Davis and Wanous, 2007; Boon, 2011), a questionnaire was developed to gauge student perceptions of the importance of sustainability and their knowledge in that domain. Students were asked about how important sustainability was to them in a range of contexts, for example, personally, as an engineer, for their country etc. In each context they indicated the level of importance on a four point scale (Not Important, Possible important, Important, Very Important). When measuring knowledge, the respondents were asked to self rate their

knowledge about particular topics (such as life cycle analysis and biomimicry) on a four point response scale (Not heard of it, Heard of it, Could describe parts of it, Could describe it in detail).

A before and after quasi-experimental design, without a control group, was adopted. The before survey was conducted during orientation week which takes place immediately before the start of classes. Students were given access to the web portal during the first week of semester. The 'After' survey was conducted in week 12, the final week of the teaching semester. Since the initiative was designed to target all first year students it was not practical to exclude students to create a control group and the time lines for implementation did not give scope to recruit an alternative control group. The absence of a control group necessitates that caution be exercised in interpreting the results in terms of attributing any measured changes to the initiative.

A broadcast email was sent to the students informing them of the survey. The broadcast email contained a link to the survey which the students could complete on-line in two or three minutes. In addition to collecting their responses to the questions on their knowledge of sustainability and their perceptions of its importance, students were asked to indicate their gender, enrolment status (domestic or international student) and their ID number (to enable responses to be matched in the before and after surveys). To encourage response, an incentive was offered in the form of a prize draw for one of ten packs containing two movie tickets. To be eligible for the prize draw students had to complete both the before and after surveys.

6. Evaluation Results

There were 977 first year engineering students who studied under the renewed curriculum in 2012. A total of 303 responded to the before survey reflecting a 31% response rate. That is a relatively high response rate for on-line surveys (Stopher, 2012) but lower than the 53% response rate reported by Boon (2011) who used paper based in class surveys when examining the sustainability beliefs and knowledge of pre-service teachers.

Of the students who replied to the first survey, 80 responded to the after survey. That represents 26% of the respondents to the before survey and an overall response rate of eight per cent. While that overall response rate is not a-typical for on-line surveys it does highlight the need to exercise caution in interpreting the results. There is a risk of non-response bias (Richardson et al, 1995) when the majority of the target population do not respond to a survey. However the power of the data collected here comes from being able to match responses from the before and after surveys on the basis of the student ID numbers. While the larger sample in the before survey ($N = 303$) provided scope to identify differences across

sub-groups that was not possible with the smaller sample of matched before and after data (*N* = 80).

Results from the before survey are presented in Figures 3 (Importance of Sustainability) and 4 (Knowledge of Sustainability). Sustainability was seen as very important for the students' country, society world wide and future generations. However when the focus was on them (personally, as an engineer or a member of the community) a noticeably higher percentage of students felt that sustainability was not important or possibly important. Students reported their greatest knowledge in relation to the definition and concept of sustainability. Knowledge levels for other factors (in terms of being able to describe all or parts) were much lower particularly for knowledge of life cycle analysis, systems thinking and biomimicry.

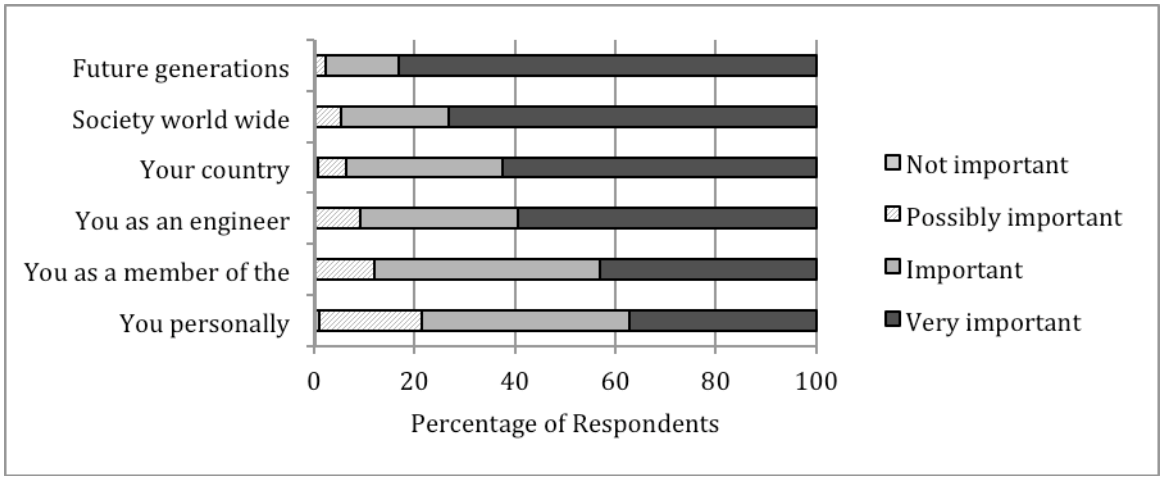

Figure 3: Student's perceptions of the importance of sustainability (Before Survey)

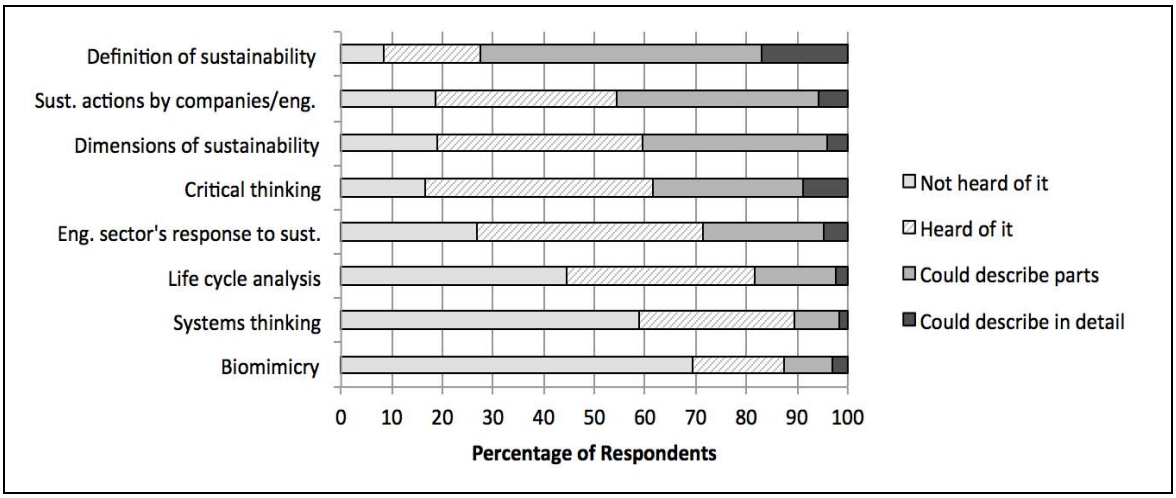

Figure 4: Student's self reported sustainability knowledge (Before Survey)

To facilitate statistical testing the average score on each factor was calculated by converting the qualitative responses to value on a 1 to 4 scale (1 = Have not heard of it, 4 = I could

describe it in detail). Testing did reveal some statistically significant differences (at a 5 % level) between the domestic and international students in terms of their sustainability knowledge but no difference between male and female students. Figure 5 shows the average knowledge scores for domestic and international students across each of the knowledge components considered in the survey. Knowledge dimensions with a statistically significant difference between the domestic and international students are highlighted with an asterisk. Statistically significant differences were observed on the first four factors with the domestic students consistently reporting higher levels of prior knowledge than their international counterparts.

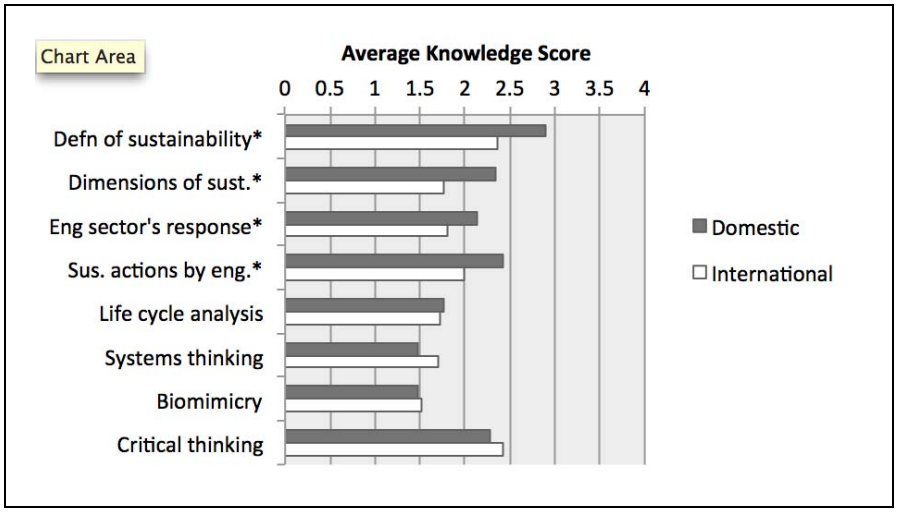

Figure 5: Average knowledge scores for domestic and international students (Before survey results with statistically significant differences, at a 5 % level, indicated with an asterisk)

In a similar manner, the importance scores were converted to a value on a 1 to 4 scale. Testing did reveal some statistically significant differences (at a 5 % level) between the importance ratings given by domestic and international students but no difference between male and female students. Figure 6 shows the average importance scores for the domestic and international students. On three factors (importance of sustainability for your country, society world wide and future generation) the domestic students reported statistically higher importance scores on average then their international counterparts.

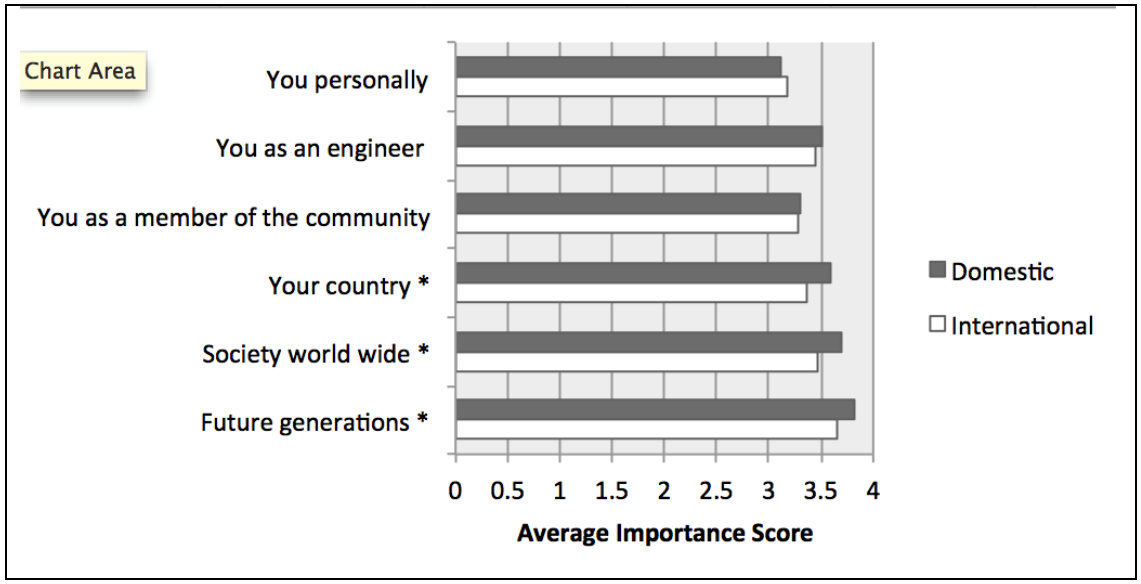

Figure 6: Average importance scores for domestic and international students (Before survey results with statistically significant differences, at a 5 % level, indicated with an asterisk).

Given that there was already quite a high level of importance given to sustainability in the before survey (average score of 3.52 on a 1 to 4 scale) it is perhaps not surprising that there was no statistically significant change in the importance rating from the before to the after period. However there was a statistically significant change in the self-reported knowledge of sustainability from the before to the after period (average score across all knowledge areas increased from 2.00 to 2.45) which was statistically significant at the five per cent level. Figure 7 shows the average before and after scores across all the different components of sustainability knowledge. Six of the eight different knowledge dimensions had statistically significant increases in the average knowledge scores from the before to the after period. Even some of the factors which were originally quite low in terms of knowledge levels (life cycle analysis, systems thinking and biomimicry) had statistically higher knowledge scores in the after period compared to the before period.

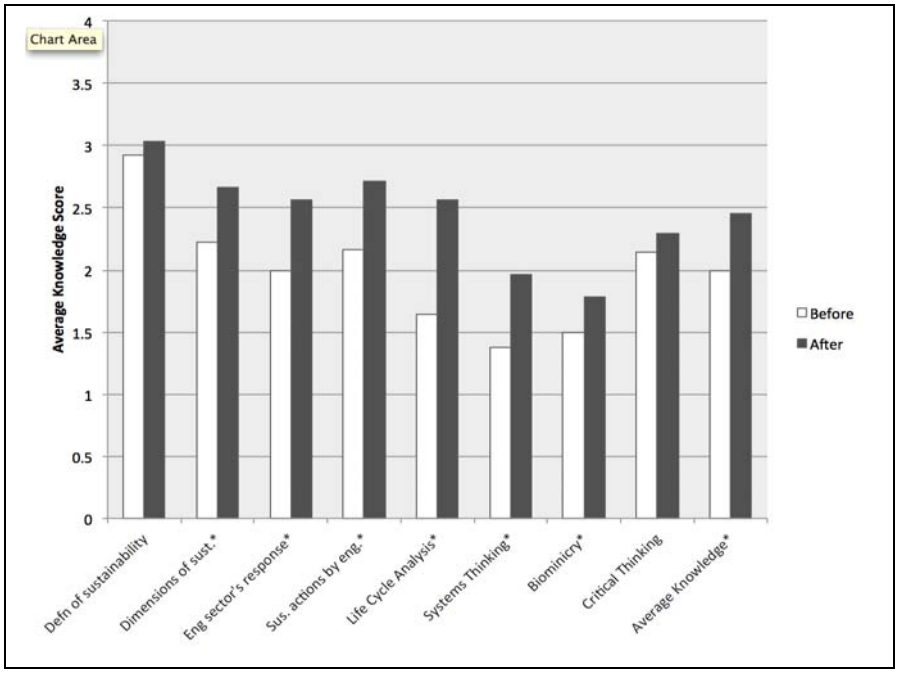

Figure 7: Average knowledge scores in the before and after survey (N = 80) with statistically significant differences, at a 5 % level, indicated with an asterisk

7. Discussion

This study has demonstrated that a collaborative process of curriculum renewal proved effective in engaging both internal and external stakeholders in identifying how sustainability could be integrated in a first year engineering program. A web portal provided a vehicle for horizontal integration of sustainability into the curriculum and there is evidence that the initiative had a statistically significant impact in terms of increasing student's knowledge about sustainability.

Wals (2014) noted that the strongest engagement with ESD has tended to be by universities focussed on teaching, rather than those that are research intensive. The initiative described here is therefore important because it was undertaken at a research-intensive university. The emphasis on inclusive, structured curriculum renewal involving a whole of curriculum approach is innovative and provides a case study of precedent in the field of education for sustainability. As noted by Watson et al (2013) there is limited insight in the literature on the process of integrating sustainability into the curriculum and this paper makes an important contribution in that respect. It is possible that the academic staff felt supported through the curriculum renewal process because it was broken up into a series of manageable steps with tangible outcomes from each stage. They were also provided with access to the web portal rather than being asked to develop it and received one-on-one coaching to identify links to their particular unit prior to the initiative being delivered to the students for the first time. This

resonates with the work of Holmberg et al (2008) who found that individual interaction with academic staff, interpreted as valuing them as sources of knowledge rather than as points of contact for teaching efforts, was effective in underpinning successful embedding of sustainability at three European universities.

Relying on a web based portal to deliver common 'horizontally' relevant material in a program represents an innovation in curriculum renewal to embed sustainability. This approach has been used in other areas where curriculum strengthening is required, for example, generic written and oral communications skills (McAvinia, et al, 2002) although in that case they judged its effectiveness using focus group and student feedback rather than undertaking any empirical measurements on learning outcomes.

While there is much discussion in the literature about the need to integrate sustainability into curricula, and describing initiatives at particular universities, few studies undertake rigorous outcome evaluation particularly to the extent of testing for statistically significant changes in student knowledge. As noted earlier the simple before and after, treatment only design employed in this study, along with the modest response rate, requires that caution be exercised in interpreting the results. Clearly there were statistically significant differences in student's self reported knowledge of sustainability between the before and the after surveys. We believe that was due to the exposure to the sustainability in first year engineering initiative. However the lack of a control group means that there is a threat to the validity of that conclusion and the modest response rate cautions against inferring that any conclusions relate to the population (the first year cohort) as opposed to the respondents. A stronger experimental design would have included a control group to account for any changes in 'environmental' factors which could contribute to difference between the before and after periods. Likewise a higher response rate would have provided greater reassurance of the representativeness of the results.

For practising engineers, the approach demonstrates that they can play a valuable contribution to curriculum renewal by assisting in the identification of graduate competency shortfalls in relation to sustainability. For education program directors, the study provides insight into an approach which can engage both internal and external stakeholders in curriculum renewal and how a web based portal can be used deliver common 'horizontally' relevant material in a program. For both individual academic staff and program directors, the study highlights the value which can be obtained through empirical evaluation of the impacts of curriculum change. The relevance of that is likely to increase over time as greater attention is given to assurance of learning.

When interpreted more broadly, the initiative described here reflects organisational learning which takes place when individuals experience a problematic situation in an organisation and study or inquire into it on the organisations' behalf (Argyris and Schoen, 1978, 1996).

Organisational and wider societal learning occurs through the medium of individuals (Jar-Thakur et al, 2009) and here it was not only the students who learned, but also the individual academic staff and those involved in program and organisational leadership. Recognition of the capacity gaps in the graduates and undertaking corrective action to renew the curriculum is a form of single loop learning (Jar-Thakur et al, 2009). However the reflecting on the initiative has served as a catalyst for double loop learning through changes in governing variables for the organisation – specifically this initiative was influential in framing one key component of the University's Education for Sustainability Strategy (Monash Sustainability Institute, 2014). To date little consideration has been given to framing initiatives to embed sustainability as a form of organisational learning and that could provide a valuable lens through which to frame and assess initiatives of this form.

8. Conclusions and Future Directions

Engineering has long been recognised as a key discipline that will contribute to a sustainable future. However, the growing global concern with the lack of sustainability content in engineering curriculum highlights the importance of learning from curriculum renewal initiatives like the one described here. Given that the strongest engagement with ESD to date has been in teaching-intensive universities, it is significant that the curriculum renewal case examined here took place at a research-intensive university. The paper has demonstrated the value of engaging in a holistic approach to curriculum renewal within the context of embedding sustainability into a first year engineering program. The series of events used to structure the process engaged both internal and external stakeholders in the curriculum renewal effort. The emphasis on manageable steps with clear outcomes assisted in retaining the interest of the academic staff and supporting them through the process of curriculum renewal. The series of workshops and meetings represents a potentially transferable implementation approach for facilitating collaborative curriculum renewal. While this paper focuses on an approach to embed sustainability within the curricula in one discipline, its broader value lies in identifying transferable learnings from, and of, the process that could have relevance to initiatives to embed sustainability in other courses. There would clearly be merit in further research to compare the success of the approach in this academic discipline with other implementation experiences, either in other engineering faculties or in different faculties.

The web-based portal developed to underpin the initiative proved to be an effective mechanism for delivering the material relating to sustainability to the students while obviating the need for staff in each first year subject to include additional lectures. The links to class sessions and assessment are likely to have been important in influencing the extent of

student engagement with the web-based portal. Further research could test how the nature of the links between the portal, classroom learning and assessment impacts the effectiveness not only of efforts to enhance education for sustainability but also in relation to other curriculum renewal efforts.

Statistically significant increases in student's self-reported knowledge of sustainability were measured in data from before and after surveys of the first year students. Those changes provide reassurance about the value of the initiative. However it is appropriate to be cautious in interpreting the results given the lack of a control group and the fairly low response rate to the evaluation surveys. Clearly future research should aim to employ an experimental design which provides the strongest possible basis for reaching conclusions about the impact of the initiative. Additional consideration could be given to fine tuning the incentives offered to students to increase the response rate in the surveys. The survey data collected prior to the start of the semester indicated that international students perceived sustainability to be less important, and also reported lower levels of knowledge of sustainability relative to their domestic counterparts. Those issues deserve further attention in subsequent research to ensure that initiatives of this nature recognise differences in starting points across sub-groups in the student population.

There is scope to conduct further research on this initiative to broaden the evaluation by considering objective assessments of student knowledge (i.e. performance on assignment and exam questions related to sustainability) as well as academic staff perceptions of the experience. Further exploration of the experience with academic staff could provide valuable insight into the extent to which double-loop learning has occurred as a result of this initiative. Extending the research in that way could shed light on the broader organisational learning which occurs through curriculum renewal initiatives.

Given the time lines and resourcing for this project, the focus was very much on curriculum renewal. Further work could also focus on evolving pedagogy to suit the sustainability component in the curriculum and to possibly underpin changes in behaviour or practice which align with enhancing sustainability. There is recognition in the literature that to make a difference the focus needs to change from attitudes and knowledge to behaviour in a professional content. There is clearly a need for further research to help understand how behaviour in a professional content changes as a result of integrating sustainability into the curriculum.

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