Enhancement of university curriculum and secondary school education through utilisation of sustainable engineering and appropriate technology workshops

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***Abstract**: Engineering faculties can struggle to find practical and meaningful tasks for students to undertake as part of their coursework whilst continuing to meet the broader requirements of Engineers Australia's Professional Engineering Attributes. Engagement between university and secondary school curriculum through sustainable engineering and appropriate technology workshops developed by Engineers Without Borders Australia (EWBA) aims to address these challenges.*

This paper outlines EWBA's new curriculum based initiative which provides university students with the opportunity to meaningfully engage with the broader community whilst educating secondary school students of the application of science to solve real world problems. The survey of teachers and secondary school students found that the program has effectively engaged secondary school students in what it means to be an engineer whilst surveys of university students has demonstrated that they have developed skills and knowledge aligned with the Engineers Australia's Professional Engineering Attributes.

Introduction

The paper presents the applicability of the Engineers Without Borders Australia's (EWBA) Future Engineers Program to enhance university's engineering curriculum and improve secondary school education. Understanding the concepts of sustainable development is one of the professional engineering attributes identified by Engineers Australia (Nafalski et al, 2001). Many professional engineers aim to work towards creating sustainable solutions, but there still exists a gap between the knowledge that they acquire in their university degree and the understanding of sustainability which they will require in their future careers (King, 2007).

The engineering context of sustainability involves the design and management of sustainable technology, research into environmental and social impacts and limitations, living within global limitations, and management of resources from cradle to cradle (Boyle, 2004). Engineering innovations need to respond to social demand, while taking ecological principles into account. University engineering degrees need to produce engineering graduates who are able to apply sustainability principles in their professional career. The Future Engineers Program enables engineering students to disseminate knowledge to the community and learn about social demands and ecological principles whilst ensuring that the lack of understanding of the engineer's role in society by the community is addressed (Goodman et al, 2002; Ambrose, Lazarus and Nair, 1998). The EWBA Future Engineers Program could also enhance the enrolment of female students, as one of five primary reasons for women entering into an engineering degree were that they were attracted to the work engineers complete, such as helping people and society or improving the environment (deGrazia et al, 2001; Goodman et al, 2002). The Future Engineers Program reinforces these attributes to help maintain student enthusiasm for the engineering profession.

The benefits of teaching secondary school students about engineering principles and encouraging them to undertake engineering as a profession is well established (Moskal, 2007; Symans, 2000). DeGrazia et al. (2001) have also demonstrated that teaching engineering in secondary schools improves the content of

classes through exposure to real world problems. The engagement of university students in these secondary school programs enhances the engineering curriculum by taking community into account. EWBA's Future Engineers program has attempted to improve secondary students' understanding of engineering and science thus encouraging participation at higher levels.

This paper will assess the benefits of the Engineers Without Borders Australia's (EWBA) Future Engineers Program to the enhancement of the university's engineering curriculum and to improve secondary school education through utilisation of sustainable technology workshops. Firstly, the paper discusses the activities conducted by EWBA to enhance the engineering curriculum and high school outreach programs. Secondly, the sustainability workshops that were conducted by engineering students in secondary schools were discussed. Thirdly, the implications of these workshops on engineering curriculum and high school program were analysed. Finally, some recommendations were made to improve the EWBA's Future Engineers Program and enable broader implementation.

Background on EWB

EWBA, a not-for-profit member-based non-government organisation, works in partnership with developing communities in South Asia, South-East Asia and Remote Australia to develop programs that support student learning of the broader context of engineering. Through this process EWB's community partners gain access to the self-identified knowledge, resources and appropriate technologies needed to improve their livelihoods. EWBA focus on developing the capacity of the local technical sector through small scale, grassroots engineering programs to ensure that innovative, appropriate and sustainable solutions to issues that impede development are locally generated and driven.

EWBA's Curriculum and Research team, in collaboration with universities, have developed a number of new and innovative education programs to support student learning outcomes, such as the EWB Challenge (Bullen, Webb and Brodie, 2007) and Undergraduate Thesis Program (Smith, Brown and Cahill, 2009), which connect student learning with EWBA work with developing communities. This paper outlines the beneficial learning experiences that could be achieved for both university students and the broader local community through a similar university based program called the Future Engineers Program. The Future Engineers Program focuses on the delivery of interactive sustainable development and appropriate technology workshops by university students to secondary school students.

Future Engineers Program Operation

Since 2005 EWBA has developed and run a volunteer based high school outreach (HSO) program. This program includes 3 independent topic areas (water supply and treatment, energy and climate change, and appropriate construction) each containing three lessons. These resources are available online and include supporting material to assist volunteers around Australia in coordinating and delivering the content (Loden, 2010) and are constantly updated based on feedback from volunteers and secondary school student participants. The benefits of easily accessible resources for conducting school outreach have been previously demonstrated (Symans, 2000). The accessible resources of the program make additional willing volunteers the limiting factor for additional outreach by EWBA. The Future Engineers Program aims to supply these volunteers whilst providing a beneficial learning environment for both secondary and university students.

The Future Engineers program was designed to be embedded within university coursework, with both Curtin University and the University of Western Australia (UWA) participating in semester one of 2010. Participating university students delivered either two or three workshops on one of the topic areas at a local secondary school. The lesson plan required the university students to explain engineering and scientific processes to secondary school students in the context of sustainable development. The university students lead the secondary school students through an interactive activity constructing a piece of appropriate technology. The program reinforces the university course work concepts of sustainable development with the participating universities students, whilst exposing secondary school students to these concepts early in their education.

EWBA worked in partnership with university course coordinators to develop the program. EWBA together with Engineering Outreach and unit lecturers provided the technical content for delivery to secondary school students, trained participating university students and coordinated the school visits. EWBA have developed partnerships with a number of organisations and schools to provide a range of schools and times when university students can undertake the activity. In order to encourage students in the sustainability area, EWBA provides certificates to the best HSO groups conducting these outreach workshops. The three sets of

workshops cover a broad range of issues. The water supply and treatment workshop introduce secondary school students to the different water treatment technologies available and their appropriateness to developing communities. The appropriate construction workshop explains various methods of construction for both developed and developing nation methods. The Climate Change and Energy workshop explains the key concepts of energy efficiency, the link between energy and greenhouse emissions and the global impacts of an increasing global footprint.

The program was run in semester 1 of 2010 as an optional activity at both universities with university students having to select to participate as a substitute for existing assessment. This was to ensure motivated and high quality participants. EWBA's role at both universities was the same however the operation within the unit differed between universities.

UWA Program

The EWB Future Engineers program was embedded into the Engineering for Social and Environmental Justice course at UWA. A team of two university students were required to evaluate the three classes delivered and improve the content through independent research or improved presentation methods. The purpose of this process was to provide an additional learning opportunity for participating university students whilst enabling continuous improvement in the education content. The best revisions were reviewed and uploaded to the website for future use. University students were assessed by written submissions being required to submit an improved lesson plan and write a report reflecting on their learning experience and how the program contributes to achieving social and environmental justice.

Curtin Program

The EWB Future Engineers program was embedded into Curtin Universities 'Engineering for Sustainable Development (ESD)' unit – a core engineering unit offered to all engineering students at Curtin University. In each semester, two to three teams of students in groups of four conducted two workshops on Water/Sanitation, and Climate Change. The task is regarded as 15% of the total assessment for the ESD unit. Because of limited time slots at school and university levels, the interested students for this assignment task are selected on the basis of their presentation ability and a quality check is performed before the workshop by allowing students to rehearse the workshop in front of EWBA volunteers and unit lecturers. In each group's presentation, the secondary school teacher and one representative from Curtin University were present to assess their work. University student teams were required to complete a two page report to summarise their workshop and learning experience.

Future Engineers Program Assessment Criteria

The Future Engineers program was assessed for its effectiveness in improving university student learning and secondary school student learning in the area of engineer's contributions to sustainable development.

Secondary School Assessment Criteria

Secondary school student learning that was measured against the Early Adolescence Science Syllabus Principles of teaching and learning (Department of Education and Training Western Australia, 2008) was used to assess how the engineering students were able to promote sustainability knowledge among the school students:

1. Learning Experiences should enable students to observe and practice the actual processes, products, skills and values which are expected of them
2. Learning experiences should connect with students' existing knowledge, skills and values while extending and challenging their current ways of thinking and acting.
3. Learning experiences should respect and accommodate differences between learners.

The first principle will be referred to as "Opportunity to Learn", the second principle will be referred to as "Connection and Challenge" and the final principle will be referred to as "Inclusivity and Difference".

To measure the effectiveness of achieving these principles feedback sheets were distributed to secondary school students and teachers. The table below outlines how the questions asked in the survey align with the Principles of Teaching and Learning.

Table 1: Secondary School Assessment Criteria

Principles of Teaching and Learning	Assessment Criteria	Questions in feedback sheets
Inclusivity and Difference	Quality of Delivery	Were you able to hear the presenter?
		Could you understand the presenter's voice?
Connection and Challenge	Knowledge & Engagement	Did the presenter seem to understand the topic?
		Were the presenters prepared?
		Did the presenters involve you in discussion of the topic?
		What did you learn from the task?
		What did you learn from the game?
		Did you enjoy the game?
Opportunity to Learn	Communication	Did the presenters clearly explain how to play the game?
		Did you understand the aim of the game before you played it?

University Student Assessment Criteria

University student learning was assessed against the development of Engineers Australia's graduate attributes for Professional Engineers (PE) that contributes to the sustainability knowledge of future engineers (Table 2). The professional engineering attributes developed are:

Table 2: Codes for Professional Engineers

Code: Short Title	Graduate Attribute Developed
PE 2.1: Problem Identification	Ability to undertake problem identification, formulation, and solution
PE 2.2: Sustainable Development	Understanding of social, cultural, global, and environmental responsibilities and the need to employ principles of sustainable development
PE 3.1: Communication	Ability to communicate effectively, with the engineering team and with the community at large
PE 3.2: Documentation	Ability to manage information and documentation
PE 3.3: Creativity	Capacity for creativity and innovation
PE 3.4: Ethics	Understanding of professional and ethical responsibilities, and commitment to them
PE 3.5: Teamwork	Ability to function effectively as an individual and in multidisciplinary and multicultural teams, as a team leader or manager as well as an effective team member
PE 3.7: Professional	Professional Attitudes

Implications of Future Engineers Program

Feedback on the program was obtained from participating university students, secondary school teachers and secondary school students.

Secondary School teachers' feedback

The secondary school teacher feedback found that the university students were effective in communicating the principles of sustainable development to their classes. Three teachers were surveyed five times during the program on the three areas covered by the assessment criteria in table 1. Whilst it is a challenging task to disseminate sustainability information to secondary school students, as they can lack the maturity to

understand the complexity of sustainability issues (Boyle, 2004; Ashford, 2004; Kelly, 2006), the quantitative and qualitative feedback from teachers demonstrates how the university students have been quite successful in engaging the students by making use of simple concepts and engaging schools students throughout the workshop with photos, graphs and interesting group activities (Table 3). These workshops were able to convey the contemporary environmental challenges to both school teachers and students, which has encouraged secondary school teachers to continue to participate in the program..

Table 3: Secondary School Teacher feedback from the Future Engineers Program

Principles of Teaching and Learning	Average score (out of 5)	School	Teacher Feedback
Inclusivity and Difference	4.4	Rossmoyne SHS, Keith Rd, Rossmoyne.	"Excellent student interactions pitched at student level."
Connection and Challenge	3.8	Willetton SHS, Pinetree Gully Rd, Perth, 6155 Como Senior High School Perth	"Their workshop was well conducted and very engaging" "Good interactions and responses – involved students well and they enjoyed it"
Opportunity to Learn	3.6	Lynwood SHS, 436 Metcalfe Road Parkwood Willetton SHS, Pinetree Gully Rd, Perth, 6155	"Good mix of presentations linked to students centred activity" "[School] are very interested in additional climate change workshops, we look forward to their workshop next week."

Secondary School Students feedback

The secondary school students' feedback found that the university students were effective in communicating the principles of sustainable development to their classes. Fifty eight students were surveyed during the program on the three areas covered by the assessment criteria in Table 4. The feedback was as follows:

Table 4: Secondary School Student feedback from the Future Engineers Program

Principles of Teaching and Learning	Average score (out of 5)	School	University Observer Observations
Inclusivity and Difference	4.5	Lesmurdi Senior High School Willetton SHS, Pinetree Gully Rd, Perth, 6155	"Students were responsive to questions and engaged and provided positive feedback." "Interesting presentations"
Connection and Challenge	4.5	Willetton SHS, Pinetree Gully Rd, Perth, 6155 Como Senior High School Perth	"The presenters have full knowledge about the supplied material and demonstrated really very well. "
Opportunity to Learn	4.5	Como Senior High School Perth Lesmurdi Senior High School	Learnt how to reduce emissions using efficient lamps and how water filter cleans dirty water for the poor people. Learnt about climate change and how they affect them.

The quantitative feedback from the students demonstrates the success of the program in achieving the principles of teaching and learning. There is a slight difference between the teacher and student feedback

which is believed to be the result of the students enjoying the activity and giving higher feedback than under a normal learning environment.

University students' feedback

Table 4 demonstrates qualitatively how university students have developed the required graduate attributes through participation in this program.Ten university student participants provided feedback on the program through written submission and response to an online survey shortly after participating in the program. The students in a team were able to fulfil all professional attributes through these workshops by professionally conveying the message of engineering sustainability challenges and working through innovative activities. These outcomes are similar to other studies (Muzaka, 2009; Moskal et al, 2007; Harland and Plangger, 2004) that found that teaching others is a beneficial learning environment for students with them developing communication skills, learning to deal with people in a professional manner, improving their team work skills and being able to transfer and apply their knowledge. These workshops demonstrated all components of sustainability, including economic (e.g. cheap water and energy options), environmental (e.g.; water treatment and efficiency options) and intra generational (e.g developing countries) and inter generational social equities (e.g. energy and water conservation).

Table 4: University Student learning experiences from the Future Engineers Program

Graduate Attribute	Student Feedback
Problem Identification	"It opened our eyes to the problematic side of engineering and how we can help - providing systematic ways to look at our impact."
Sustainable Development	"The problems of accessing clean drinking water for developing communities were presented to the students. This gave the students an idea on the importance of helping these people through appropriate and sustainable technologies."
Communication	"It was a good experience as it enabled both my presentation and communication skills to improve." "One of the skills acquired through the program was the ability to transmit the information in such a way that the audience can relate to. By simplifying the technical aspects of sustainable development and only conveying fundamental topics of the current situation, we found that the students could absorb the information easier."
Documentation	Students are required to write a report documenting their learning experience.
Creativity	The program has created a stable foundation for public speaking as well as inspiring the group to continue with various EWB volunteer programs.
Ethics	"The problems of accessing clean drinking water for developing communities were presented to the students. This gave the students an idea on the importance of helping these people through appropriate and sustainable technologies."
Teamwork	Students are required to work as a team to complete the workshop. " It was a nice experience as a group and as an individual." "The task of organizing the students into small manageable groups wherein each student got the opportunity to dynamically participate in the activity gave the group insight into efficiently coordinating a large number of individuals in an orderly manner."
Professional	Students are presenting to an external audience and are assessed on how they conduct themselves.

Other than fulfilling Professional Engineers' attributes, these workshops will contribute to the rapid curriculum renewal for the engineering faculties of Australian universities in order to overcome a "time lag dilemma", whereby the standard curriculum renewal approach to embed new knowledge and skills within the curriculum may take too long, lagging behind industry, regulatory and accreditation shifts (Desha et al. 2009).

Potential Future Benefits, Plans & Challenges to overcome

The potential future benefits of this program include the following:

- Increased student community involvement achieving behavior change in the student population
- Ongoing participation in EWBA programs and other socially aware organizations
- Broader awareness within the high school student population, increasing the number of people aware of these issues and willing to drive behavior change within society
- Increased engagement between universities and EWBA connecting students to community and the broader challenges that engineers and society face today.
- Increased critical mass, for example, the number of Curtin students participating in the workshops increased from 8 in semester 1 to 12 in semester 2.

This program could be integrated into university engineering curriculum in the following course types:

- Sustainable Development and Environmental Engineering courses
- Subjects containing specifically Energy, Water or Construction content (utilising the specific modules developed)
- Communication Courses
- Ethics and Social Justice programs
- Other than engineering, similar outreach tasks can be introduced to other faculties within universities, such as environmental biology, built environment and architecture

We plan to continue this program and look to expand its operation into other universities, expanding to 5 universities in 2011. As this expansion occurs we intend to conduct more detailed and formal monitoring and evaluation of the program to enable continuous improvement.

The major challenge of running the program on a larger scale is the development of relationships with local secondary schools across the country, which requires substantial time and resources. It is possible to utilise the existing relationships that students, universities and EWBA have in place to deliver the Future Engineers program within coursework, without a significant increase in workload. Many university outreach programs and EWBA chapters have an existing relationship with local schools that could be provided to assist the program. Participating students could approach their past secondary school to conduct the workshop using a relationship with the prior science teacher. By utisiling the EWBA resources, a university coursework's assessment requirements and the relationships of students and outreach programs it is possible to include this program into the engineering experience and improve the learning outcomes for participating university and secondary school students.

Conclusion

This program has been demonstrated to be both beneficial to university students through the development of graduate attributes and secondary school students through the enhancement of the principles of teaching and learning. The program is designed to be implemented in multiple universities and secondary schools around Australia.

Through participation in the EWB Future Engineers program participating engineering students were able to further develop eight of the Engineers Australia Professional Engineering attributes. The skills developed were in areas that university coursework programs traditionally struggled to develop these attributes, covering areas such as communication, sustainable development, ethics and creativity. Secondary school students benefited from participation by supporting the goals of teaching and learning from the early adolescence science syllabus. The learning experience focused on giving students practical learning environments, providing different ways to learn the content of the workshop and exposing them to the wider applications of science and engineering to the sustainability challenges of the world. The interactive workshops were an enjoyable and positive experience for both the university students and the secondary schools students which ensure a beneficial learning environment.

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