Teaching Sustainability Using Project Based Learning

Julia Lamborn
Swinburne University of Technology

ABSTRACT
Embedding sustainability in curriculum is a requirement of all engineering programs, however, the reality is that many engineering programs have not embraced this to the extent that Engineers Australia would expect. One method of exposing students to sustainability is by embedded it within project based learning subjects.

INTRODUCTION
All engineering students need to be equipped with a wider horizon of concepts in terms of environmental, economic, and social attributes, for decision making that is sensitive to sustainability issues. Sustainability needs to be introduced in the early years and built on throughout the program (Allenby et al. 2007). Engineers Australia sets out in the accreditation documents for engineering courses the requirement for graduates to understand the social, cultural, global, environmental and business responsibilities of the Professional Engineer and understand the need for and principals of sustainable development (Engineers_Australia 2008).

One of the best ways to achieve the development of sustainability skills as well as the development of the associated graduate attributes is by means of project based learning in the later years of the course using industry projects (Tullis et al. 2001). In the later years of an engineering program, students bring together all the skills they have developed in the previous years’ study. Project based learning is a good method for letting the students explore an engineering project that takes into account the sustainability, environmental and social aspects (Gaughran et al. 2007). This paper will present discuss one such subject offered at Swinburne University of Technology in the Civil Engineering Program.

PUTTING PROJECT BASED LEARNING INTO PRACTICE
Project based learning is normally a group activity that extends over a reasonable period of time, resulting in a product, presentation, design, report or solution (Chau 2005). It typically has a timeline and milestones and other aspects of formative evaluation as the project proceeds. Students in the final years of their course should be exposed to the open ended multi disciplinary projects that exist in industry (Tullis et al. 2001). They need to develop the skills to appraise, analyse, investigate, research, acquire and understand knowledge outside their main discipline area, liaise with other engineers and professionals, sift through data and information to locate the critical knowledge required to solve the problem, form and justify assumptions; and produce and present a logical and well reasoned solution (McIntyre 2002).

When considering project based learning with respect to sustainability the students need to:
• Understand the application of environmental and sustainability principles to create sustainable practices in engineering projects
• To recognise and experience the multi disciplinary nature of sustainability
• To develop the multi disciplinary knowledge and skills required to practice as an engineer with a sustainability focus.

There are often a number of issues in implementing project based learning within the curriculum. One of the most common is the extra time required on the part of the academics to plan, set up and run such subjects (Chau 2007). Their workload, in many cases, is already high and extra time is not normally granted within university workload models for such subjects. In addition, the curriculum is by default ‘full’ and staff are reluctant to allow their subject to be removed to include new material such as a project base learning subject.
Another issue can be the lack of ability of individual staff to teach within a multi-disciplinary context and in particular with environmental and sustainability concepts. It is the perception by many academics, particularly those who have been in the system for many years, that sustainability is about ‘tree huggers’ or ‘saving the planet at the expense of progress’ and really has nothing to do with their discipline (Allenby et al. 2009). This lack of understanding that sustainability is a necessary part of all engineering disciplines will take significant effort to overcome (Gaughran et al. 2007). Also many staff do not have the background to undertake this role of teaching engineering within a sustainability context and therefore engineering education community needs to consider the development of suitable training for academics to help in this regard. The result of this lack of multi-disciplinary expertise by many academics, results in the students lacking the ability to identify and value the contributions of multiple fields to a complex problem (Richter et al. 2009). Without suitably trained and qualified academic staff, the future engineers of tomorrow will not leave the university system with the right skill set.

**HES4146 WATER AND ENVIRONMENTAL ENGINEERING**

This subject is undertaken in the final semester of the third year of the civil engineering program at Swinburne University of Technology. Students carry out a major investigation project in small groups including design, feasibility studies, investigation and specification. The projects are chosen in the fields of water and environmental/sustainability engineering.

The aims of the subject are:

- To prepare students in a professional team-working environment
- To direct students to appropriate resources and recognise the current water and environmental/sustainability related issues by giving students an opportunity to tackle real up-to-date water and environmental engineering projects in practice with the theme of sustainability
- To develop and present a high quality design feasibility study
- To provide students with the opportunity to experience peer reviewed oral presentations
- To develop student’s confidence in public speaking and enhance communication skills

At the end of this course students should be able to:

- Plan, manage, coordinate and deliver water and environmental projects
- Integrate sustainability theme in the project appropriately and practically
- Identify problems in the project and consult productively amongst group members
- Examine and assess the validity of supplied data and information and correctly locate errors, where appropriate
- Critically review literature on topics under investigation

**ISSUES IN SELECTING PROJECTS**

For this subject a new project is selected each year. This ensures that copying from previous years’ reports does not occur. When this subject was first introduced real, current projects were used. This meant that students were given access to current, recently finished or soon to be started projects. However, it was found there were significant issues with a large group of students being out on site, contacting authorities etc at a time when a contractor was either undertaking the project or in the process of tendering for a project. Issues arose with respect to the confidentiality of data, access to sufficient information to enable the project to be undertaken, delays in the real project and the timeliness in the availability of data compared with teaching semester time restrictions. In a number of cases, approval to use the data from a particular project required the university to sign confidentiality agreements with companies. Therefore, there were often significant lead times required to set up such projects. In a couple of cases, the company withdrew its approval a couple of weeks before the teaching semester commenced, leaving very little time to set up another project.
As a result of these issues, it was decided to use simulated projects rather than real, current projects for this subject. Simulated meant that the project wasn’t actually being undertaken however, the sites selected and data that the students used for the project were real. The projects selected were possible to be considered by the water authorities in the future, particularly considering the long on-going drought in Victoria.

By using projects at real locations, it enables students to visit the site and get an appreciation of the complexity of real full scale, multi disciplinary projects and the issues that were likely to effect any solution. The students need to develop the skills in sorting through a large amount of data, realising that not all data is provided and therefore making appropriate assumptions and dealing with conflicting agendas to be able to develop a logical and justifiable response to the selected project. It is important to select a project that is multi disciplinary, open ended and exposes the students to sustainability issues. Some projects do not have the multiple levels of complexity to maximise the benefit of undertaking the project. It is important for students studying any engineering discipline that they are presented with projects covering environmental and sustainability engineering.

**HES4146 SUBJECT DETAILS**

This subject covers the development and application of a project based learning approach to the design of sustainable urban water management systems for Victorian communities. Students are invited to investigate options for making a water authority’s operations more sustainable. In the past few years a number of different water authorities around Melbourne have been used for this project, Yarra Valley Water, South East Water and City West Water. These water authorities were chosen for this project as they provide an example of a regional water supply organisation, supplying a number of small regional communities with potable water and sewerage services. Such operations provide an ideal scale for student project based investigations of water infrastructure, as the project can be realistically constrained to highlight specific aspects of interest. In one year, the project was structured around the design of infrastructure for supplying recycled sewage to the Healesville community.

Students are initially asked to consider the sustainability issues facing a water supply organisation such as Yarra Valley Water, where the current debate centres on two related aspects. The first issue relates to the recent dry weather conditions throughout Eastern Australia and their current demand for potable water, which will significantly impact future economic growth in the region. There are strong community concerns that current water management strategies are not sustainable in the long-term. The second issue relates to the future growth in demand for potable water, which is expected to have a significant impact on the natural environment, and any damage to this environment is likely to reduce the liveability of the area.

This project is presented in the form of a “real world” engineering design scenario, in which water authority has identified their desire to improve the sustainability of supplying potable water to its customers. With this in mind, they would like to develop a showcase example of sustainable water management in a regional town, for example the Healesville or Kooweerup area. This example would be used to showcase best management practice concepts throughout the water management industry. It would also have the aim of improving students’ skills and knowledge-base in sustainable water management practice.

In this scenario, the students take the role of an engineer, within an engineering design organisation, which has been approached by the water authority to undertake a preliminary study into the feasibility of developing a sustainable water management system for the selected area. The brief from water authority states that the organisation is to:

(i) Identify sustainable water management strategies for the selected area;
(ii) Identify the environmental impacts that will result from the use of these water management strategies;
(iii) Identify strategies to mitigate these impacts, and;
(iv) Provide a preliminary sizing of the infrastructure required with associated costs.

Students are asked to organise a small team from within their peers undertaking the subject, to work on this collaborative team-based project. This approach provides significant educational advantages, as it allows students to undertake their learning within a supportive collegial environment, taking advantage of the student’s already developed peer support network. Students are also better able to investigate more complex “real world” design strategies by collaboratively working with their colleagues to synthesise ideas covering the social, economic and environmental constraints and develop engineering solutions which are able to address these often conflicting issues.

The project has been structured so that students are first introduced to a broad open-ended scenario, highlighting the complex social and environmental issues faced when sustainably managing water resources in Australia. They are then asked to identify solutions, and investigate the issues to be addressed in designing a sustainable system. Each week, the focus is narrowed so that they are directed towards a specific system that can be designed using an appropriate level of engineering analysis. In this way, students are introduced to the “big picture” of sustainable resource management whilst being nurtured through the development of an appropriate solution, without applying either simplistic technical analyses or complex “black-box” engineering solutions. They are then more able to appreciate the open-ended nature of design, without adopting the “sink or swim” approach common to many project-based approaches to learning.

The project is supported with weekly lectures covering various aspects of the project, timed to match the sequence of issues raised. Each team is encouraged to attend a weekly 15 minute meeting to discuss the status of their project, plus undertake five milestone assessment items, in which the teams provide details covering a specific aspect of their project. These milestones are assessed by the teaching team, who provide written feedback to the design team on aspects of their investigations, especially identifying issues that need to be more fully addressed. Each team must submit a design report and a design calculation file including demonstration of a quality assurance process, plus undertake a seminar outlining the outcomes of their study. Assessment criteria are provided at the beginning of the project for all assessment items, which aim to unambiguously identify each of the criteria assessed, and define the nature of work that constitutes each level of attainment within these criteria. The assessment criteria are designed to recognise the importance of following a logically structured design process based on reasoned investigation and analysis.

FEEDBACK FROM STUDENTS
This subject has been running in the current form for four years. However, there have been a number of changes made during this time to improve guidance and support provided to students. In particular, the addition of the five milestone tasks, to be submitted at regular intervals throughout the semester. These enable regular feedback to be provided to the students regarding their progress on the project. Previous student feedback on this subject had highlighted that the students wanted regular feedback on their progress to ensure they were on the right track and resolve any issues prior to the submission of the final report.

All Swinburne subjects have student surveys each semester for the subject (student feedback on subjects: SFS) and the teaching (student feedback on teaching: SFT). From the results of the SFS, comments were received in the early stages of this subject such as:

- We have had no feedback and it is week 9. I could well be on my way to failing and would have no idea
- Need much more feedback
The addition of these milestones made a big difference in the way the students felt about their progress with the project and gave them confidence in their ability to handle the complex project. The subsequent SFS comments included comments such as:

- **Milestone feedback ensures good progress on the assignment**
- **The subject was interesting and informative and applied the last three years work**
- **It was good to have relevant topics and projects to work on that were similar to real life engineering designs**

**ADVANTAGES TO THE STUDENTS OF PROJECT BASED LEARNING**

Such projects provide an ideal scale for student project-based investigations of water infrastructure, as the project can be realistically constrained to highlight specific aspects of interest, whilst motivating and inspiring students to learn through the solution of “real world” problems (Erdogan et al. 2009). Even though the projects selected were not actually being constructed, students appreciated that they could easily occur and felt they were involved in the type of project that would happen in industry. Engineering students generally place a great deal of emphasis on tasks that they see are directly related to engineering practice (McCormick et al. 2008).

The students are given the opportunity to learn about a broad range of issues covering the sustainable management of water resources in Australian urban communities. They are then motivated to develop their knowledge and understanding by applying ideas, concepts and theory to a “real world” scenario. Most students are familiar with many of the social and environmental issues related to this project, as the sustainability of urban water resources resulting from potential climate change is a popular topic in the modern media. However, they are unfamiliar with ways in which they might address these issues from an engineering perspective. The project-based approach adopted allows students to take theoretical engineering concepts that have been introduced in other subjects and apply them to design a system which satisfies the multiple constraints imposed in the “real world”. They feel that the skills learnt and final report from this subject provide an excellent resource to take to a job interview to demonstrate they are capable of dealing with multi-disciplinary projects and the application of engineering knowledge to complex real issues.

The students are able to develop a much broader range of engineering design and analysis skills than is possible from a traditional lecture-based format. The normal lecture-based delivery, that is typically used more in the early phases of an engineering program, is not suited to the investigation of solution options that depend on analysis of many technical and non-technical issues, the development of various options and the justification of the underlying assumptions that were required to been made for each option. This approach can challenge many students who are used to teacher focussed learning.

Therefore, the project is structured so that students are not “thrown into the deep end”, but are led through the design process. This is a difference between the delivery of this subject and other project based subjects reported in the literature. This supported leading of the students is supplemented with clearly defined milestones, feedback on group progress and formal lectures on relevant theory. The students are inspired to further develop their own learning as most students recognise the importance of developing broad engineering based skills as part of the training for their future engineering careers.

Students are encouraged to consider ideas and issues beyond the minimum constraints that have been set as part of the project description. This motivates students to consider learning as an active process, in which they are able to direct their own learning, whilst still remaining within the structured framework of the project. The weekly meetings with each team also reinforce this “self-directed” approach by providing a learning environment where students are encouraged to investigate issues within an environment that is less threatening than that adopted with traditional assignment based subjects. The weekly meetings can facilitate the timely correction of any misunderstandings made by a team, without causing serious setback.
to the team’s progress. Teams can also canvass ideas and approaches to their project from the teaching team at these meetings, which they are then able to adopt as part of their analysis. The teaching team can also proactively identify aspects of the team’s activities that may need to be addressed by the team.

By addressing issues identified at these team meetings, the teaching team is also able to identify aspects that require further discussion within the more formal lecture environment. By focussing the project around a “real world” design scenario, the students are encouraged to structure their learning using the professional engineer as a role model. The students are encouraged to direct their activities towards issues that are driven by the nature of the project and the physical constraints imposed by the site. This is one of the most motivating and inspirational aspects of this teaching process, is that most students appreciate the importance of developing professionally relevant skills and they are better able to appreciate the relevance of theory when it is developed within the context of a practical engineering outcome. With this approach students come to view their lecturers as engineers rather than just educators.

CONCLUSION
Sustainable engineering poses a difficult set of challenges for engineering educators. However, project base learning is a good method of delivering the concept of engineering design within a framework of sustainability to students. The experience learnt from the delivery of HES4146 Water and Environmental Engineering over the last seven years has greatly improved the subject. This subject currently is much more student focused than it was previously and the selection of simulated projects has ensured a better and more guided outcome for students. The students have reacted positively to the changes in this subject and have stated in subject reviews that it has been one of the highlights of their program, even though many students were originally over-awed by this subject during the first few weeks of the semester.

The development of engineering projects within a team-based delivery, allows students to increase their abilities to work in teams, highlighting skills that will be expected upon graduation. Students need to learn how to apply sustainability principles within an engineering context and practise of these principles in a supported and controlled environment is an excellent approach.

REFERENCES
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BIOGRAPHY

Julia Lamborn is the Director, Industry Liaison, Faculty of Engineering and Industrial Sciences and the program coordinator for civil engineering at Swinburne University of Technology. She has been a lecturer at Swinburne for 19 years and prior to that was a cooling tower thermal design engineer at the SECV for 8 years. She has research interests and expertise in landfills, waste management, environmental impact assessment, environmental engineering, engineering eduction, cooling towers and engineering heritage. She is very active for over 27 years in Engineers Australia and currently is the Deputy Chair of the College of Environmental Engineers.