Engineering Sustainable Solutions: Education Program -

Putting Sustainability as a 'Critical Literacy' into Mainstream Engineering Curricula

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Abstract.

While a number of universities in Australia have embraced concepts such as project/ problem based learning and design of innovative learning environments, there has been a lack of national guidance on including sustainability as a 'critical literacy' into all engineering streams. The positive role of Australia's peak engineering body, the Institution of Engineers Australia (Engineers Australia) is presented, in the context of its ability to accredit university engineering courses, and its responsibility to ensure delivery of sustainability education material to students.

This paper then presents the results of a current initiative to address the 'critical literacy' dilemma. Engineers Australia provided a grant to The Natural Edge Project (TNEP) to develop an introductory education module for environmental engineering

students, as part of a larger proposed "Engineering Sustainable Solutions: Education Program". It is intended that TNEP will then develop the remaining modules to complete the program, which will be made available for use by universities or other education facilities. It is envisaged that such a program will help universities to meet a certain level of sustainability content, as part of possible future accreditation requirements by Engineers Australia, or indeed other similar international accreditation bodies.

Part of the introductory module to the program was trialled at Griffith University, with first year environmental engineering students, in May 2004. The paper summarises lessons learnt during development of the first module and conclusions reached for future module development.

The authors are members of the TNEP secretariat - an ongoing, not-for-profit partnership driven by a group of young engineers and scientists based in Australia. The team is hosted by Engineers Australia and receives mentoring and support nationally and internationally from a wide range of individuals and organisations, in business, government and in research. The project is focused on assisting nations, through a whole of society approach, to achieve sustainable genuine-progress.

INTRODUCTION

Background

The 2002 EESD conference reaffirmed the importance of a comprehensive strategy for building a sustainable future - one that is equitable for all human beings. This was originally highlighted by the Rio Conference (United Nations Conference on Environment and Development) in 1992 and was confirmed at the recent Johannesburg Conference in 2002. Such a strategy requires, "*a new frame of mind, new sets of values and new technologies that are ecologically, economically and socially sound*" (EESD, 2002). Universities are increasingly being asked to play a lead role in developing multidisciplinary and ethically oriented education, to work towards solutions related to sustainability issues.

In addition, the previous conference emphasised that, "*Engineering education at all levels, especially higher education for the training of decision-makers, researchers and teachers, should be oriented towards sustainable development and should foster environmentally aware attitudes, skills and behaviour patterns, as well as a sense of ethical responsibility*" (EESD, 2002). Five key areas of interest were identified by the delegates:

- The role of institutions of engineering education;
- The need for teaching a new paradigm in engineering education;
- The critical need to integrate course material with social science material;
- The type of educational material taught within engineering disciplines; and
- The importance of developing and sharing good teaching practices in this field.

Scope of the paper

This paper uses an Australian case study to demonstrate how sustainability as a 'critical literacy' can be integrated into engineering education, to help engineering

students understand their role in moving society towards a more sustainable way of life. Key items of importance include:

- The development of sustainability curricula for all engineering streams;
- Consideration of national coordination of sustainability education material; and
- Use of a whole of society approach to content review and development, including a university trial and future peer review by Australian and International mentors.

Project involvement

A number of key bodies have been involved in the project to date, including The Natural Edge Project (TNEP, www.naturaledgeproject.net), the Engineers Australia Environment College (www.ieaust.org.au) and Griffith University (www.griffith.edu.au). TNEP also plans to use its existing network to provide an international peer review of the material. It is envisaged that the panel will consist of key academic, industry and government representatives interested in sustainability education.

AUSTRALIAN ENGINEERING CURRICULA OPPORTUNITIES

While a number of universities have embraced concepts such as project/ problem based learning and design of innovative learning environments, there has been a lack of national guidance on including sustainability as a 'critical literacy' into all engineering streams at universities. While some universities have embraced sustainability into curricula in some or all of their studies, other universities are yet to follow suit.

The role of professional bodies in Australia

It is clear that if sustainability is to be included into university curriculum, the relevant professional body for the particular discipline will need to be one of the driving forces. The World Federation of Engineering Organisations recognises this on their website (www.wfeo-comtech.org) and in their online publication (Committee on Technology, Engineers and Sustainable Development, 2002).

Within the Australian engineering profession, Engineers Australia (EA, the national peak engineering body) recognises that the engineering profession will play a significant part in moving society to a more sustainable way of life. The Australian Engineering Code of Ethics statement (EA, 2000) contains a direct imperative for engineers to include sustainability considerations in their daily work, stating in Tenet 6 that, "Members shall, where relevant, take reasonable steps to inform themselves, their clients and employers, of the social, environmental, economic and other possible consequences which may arise from their actions".

EA's national president is clear about the need to move forward on education for engineers in sustainability, "*It is up to engineers to consider sustainability in every project they design and construct & every product that is made. Sustainability is now a fundamental responsibility that all engineers must carry every day*." (*pers com* D. Jones, President, EA, 2004). At a national level, EA has been publishing documents related to engineering and sustainability for more than a decade. These include reports on Sustainable Energy (EA, 2001a), Energy Innovation in the Commercial Buildings Sector (EA, 2001b), Sustainable Transport (EA, 1999), and Towards Sustainable Engineering Practice - Task Force on Sustainable Development (EA, 1997). In 2004

the professional body is in the process of forming a national sustainability initiative and the Environment College which sits within EA is also driving the development of sustainability education material.

The development of such documentation and material sits well within EA's objectives and indeed helps EA to continue to provide service to its members and the community. In January 2004, the Environment College, on behalf of EA, provided a grant to The Natural Edge Project for the development of the Introductory Module, between February and June 2004. This was the first step in developing a larger "Engineering Sustainable Solutions: Education Program". As the EA national president states, "We need to respond to the overarching responsibility for engineers in the application of our engineering education, training and experience to provide excellent sustainable engineering solutions for the benefit of our employees, clients and the community" (*pers com* D. Jones, 2004). The development process can be shown in **Figure 1**. The following paragraphs describe the material and its context in the overall proposed program.

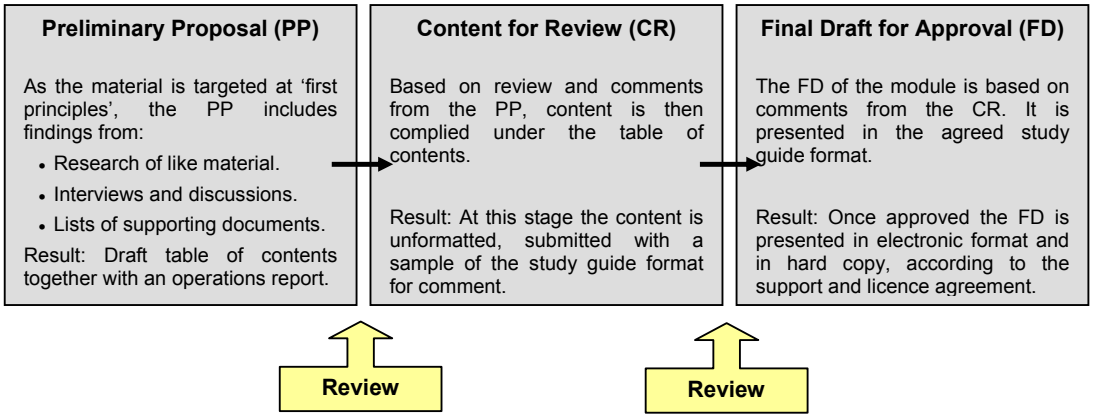

Figure 1. Introductory Module Development Process.

ENGINEERING SUSTAINABLE SOLUTIONS: EDUCATION PROGRAM

The aim of the project is to enable key pieces of information, or so-called 'critical literacies' relating to sustainability, to be incorporated as effectively as possible into the broadest range of engineering curricula. The project is intended to compliment other student studies as an alert to sustainability principles and activity in the engineering profession. This paper focuses on introductory material which begins the program, as described in the following paragraphs.

ESS Program Matrix

The Engineering Sustainable Solutions: Education Program (ESS Education Program) is split into 'Student Entry Level', followed by more technically advanced material, as shown in **Figure 2**. The entry level material is currently being developed and it is intended that the more advanced education modules on particular topics will be developed under a separate grant.

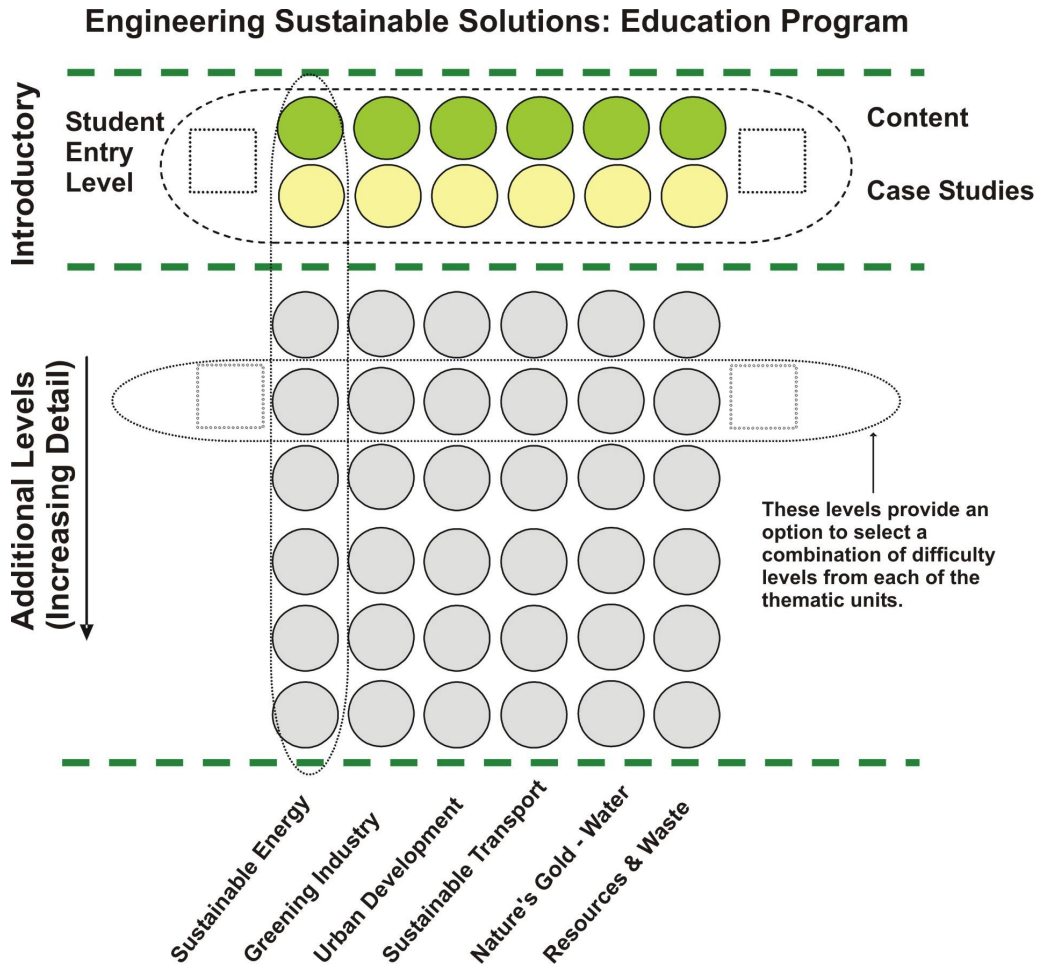

Figure 2: Diagram showing proposed layout for the Engineering Education Solutions: Education Program

The program is comprised of a number of individual 'Modules'. Each module contains six individual 'Technical Units', designed to be delivered with an introductory and concluding unit to suit the audience and trainer. The units may be delivered in either a full day workshop, in a series of one hour lessons or over a given period as part of a larger course or program. Each module is supported by The Natural Edge Project's publication, *The Natural Advantage of Nations* (Hargroves and Smith, *Forthcoming*) and online companion web site (www.naturaledgeproject.net).

This paper describes the production of the 'Introductory Module', which is located within the student entry level part of the ESS Education Program (dark shading in **Figure 2**). It is noted that the entry level also includes a second module, which focuses on detailed complementary case studies.

Content Outline

The introduction module contains three key resources, which are described in the following paragraphs:

- A trainer's guide;
- A study guide; and
- A companion web site.

Trainers Guide

The Trainers Guide comprises a word document and a base set of example presentation slides for each unit. The document provides background information to the trainer on the module and its functionality, to ensure that the trainer can make the most of the tools available. It should be noted that the power-point slides contribute to the Trainers Guide by providing an additional base resource for trainers when creating their own slides. Indeed, these presentations are not intended to be used as the primary source of information.

Study Guide

The intent of the study guide is to provide the trainer with a set of information to teach from. The ESS Education Program's introductory module contains six 'Technical Units', covering the following topics:

1. A New Perspective
2. Learning the Language
3. Effective Communication
4. (a) Energy Use (b) Greening of Industry
5. (a) Greening the Built Environment & (b) Sustainable Urban Transport
6. (a) Water – Nature's Gold & (b) Achieving 'Zero Waste'

Technical Units 4 to 6 each contain two major topics. The layout of the units within the module is shown graphically below in **Figure 3**.

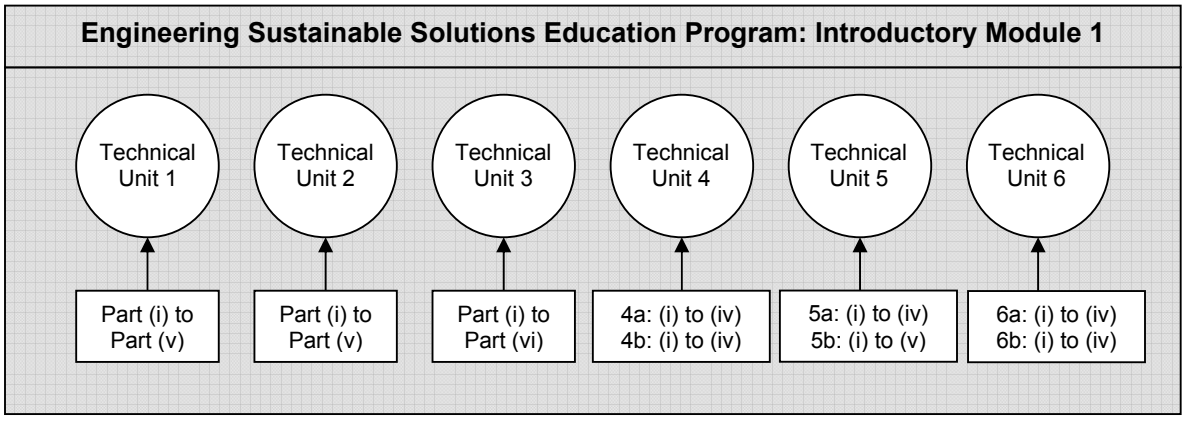

Figure 3: Module layout, showing the use of units and parts to separate material

As shown in **Figure 3**, each Technical Unit contains four to six 'Parts', to assist trainers in dividing up the lesson. For example, Technical Unit 1 content is split into the following Parts:

Part i) Setting the Context – A Global Summary
Part ii) What has lead to a lack of Sustainability?
Part iii) Platform for Change: Sustainability a Driver for Innovation & Enabling Technologies

Part iv) Implications and Benefits for Global Development
Part v) Fitting into the Picture: Engineers & Sustainability

Within each Part, there are several sub-headings, which are described below in **Table 1**.

Educational Aim:	This provides a short snapshot of intent - the key message for this Part of the Technical Unit, as an overall guiding aim for the trainer. The trainer may use this as an introduction to the class.
Learning Points:	The learning points list the key items to cover during this Part of the Technical Unit. The text has been formatted so that it can be easily copied onto overhead slides.
Brief Background Information:	Brief background information is supplied to the trainer, to provide some context to interpret the key learning points. It also indicates the type of information contained in the recommended references and resources. Often, this material explains terminology further, or gives background information to help further explain concepts in case students find the material difficult to understand. This additional information could also be used to prepare student handouts, or as additional reading for students.
Key References:	This list is very important as a summary of where key information has been sourced, and where more information on related topics can be found.
Key Words for Recommended Web Sites:	Key words have been provided as well as web site addresses, due to the amount and frequency of address changes on the internet. With the vast search capabilities of current search engines, a search on these key words will also list the most current material available on the topic of interest.
Assessment Questions and Activities:	A number of questions and activities have been provided for each Part of a Technical Unit, to help check whether the students have understood the key terms and content. The questions are intended to be 'memory joggers', to be used as a quick quiz at the end of the unit, or at the end of each part of the unit, depending on the preferred teaching style. The activities could be undertaken as a workshop session, or could be carried out by the students as 'homework' or a short take-home assignment.

Table 1: Key content headings within each Unit layout

In summary, the 'Educational Aim' defines the educational objective for each Part. The 'Learning Points' summarise key points to explain or justify the message. These learning points are then supported by some 'Brief Background Information' and recommended 'Key References'. 'Assessment Questions and Activities' are suggested, where the questions are intended as memory joggers for the students.

In the preparation of any education program, and in particular an introductory course, it is a challenge to cover all possible questions or uncertainties that may arise or be asked during delivery of the material. In response to this challenge, the program is designed so that it is supported (ie in its critical academic rigour and structure) by engineering related material in the publication, *The Natural Advantage of Nations* and companion web site. Therefore, concepts and information presented in each module are also covered in more detail in the book and online additional reading lists. If and when trainers or students seek additional information or justification of content presented in the module, they can search the online site for assistance, and/or read the chapter of the publication that corresponds to the associated unit. This provides a 'one-stop shop' type of environment that makes teaching and learning as easy as possible.

Content collated for the Introductory Module (and the rest of the program) also contains references to key recommendations by significant government and institutional

reports, forums and councils. These include:

- The World Federation of Engineering Organisation's sustainability related reports.
- Institution of Engineers Australia's relevant taskforce reports on sustainable energy (EA, 2001a, 2001b), sustainable transport (EA, 1999), and sustainable engineering practice (EA, 1997).
- The Australian Government's National Environmental Education Council and Environmental Education National Action Plan.
- The South Australian Environment Industry Cluster Development (Department of Industry, Science and Resources, Emerging Industries Section, 2001).
- Recommendations from significant national and regional forums like the CSIRO FutureCorp forum.

Companion Web Site

The companion web site has been developed to facilitate further learning and to ensure that the module does not become out of date as soon as it is published. An example excerpt from the companion website that relates to Unit 4a (Energy) is given in **Figure 4** below.

Energy and Climate Change

i) Introduction to Cost Effective Greenhouse Solutions

Adjunct Professor Alan Pears writes. "(Greenhouse Gas) Emission reduction sounds like a daunting prospect, and many people imagine that we will have to freeze in the dark, shut down industry, and face misery. But remember, we don't have to slash greenhouse gas emissions in a couple of years - we are expected to phase in savings over decades. This allows us to take advantage of the fact that most energy producing or using equipment, from fridges and computers to cars and power stations has to be replaced every 5 to 30 years. So we can minimise costs by making sure that, when old equipment is replaced, low greenhouse-impact alternatives are installed. For example, by 2020, most of Australia's dirty coal-fired power stations will be more than 30 years old - and they will have to be re-built or replaced: renewable energy, cogeneration and high efficiency energy supply technologies (such as fuel cells) could replace them. Similarly, most household appliances are replaced every 15 years: in 2005, you will be able to choose a super-efficient fridge that generates a third as much greenhouse gas as today's 5 star fridge."

Read full article | View Further papers by Alan Pears

Figure 4: Example of web layout, showing the use of summary text and reference to material.

The importance of case studies

Books like Natural Capitalism: The Next Industrial Revolution (Lovins *et al*, 1999), the case studies on the Australian Conservation Foundation (ACF)'s Natural Advantage: Blueprint for a Sustainable Australia (ACF, 2000) and the Western Australian State Sustainability Strategy (Department of the Premier and Cabinet, 2003) show that right now we can achieve genuine sustainable progress. For students who are new to the field of sustainable development, it is helpful to start with particular case studies and success stories. Indeed, the publications noted above contain many such examples.

Case studies and stories are important as they show what has already been achieved

and therefore in principle what can be duplicated, or indeed improved upon. Case studies and stories save a great deal of discussion about whether particular sustainability goals can be achieved, proving that steps have already been taken by someone, somewhere, already. They also help to avoid 'reinventing the wheel'. When someone asks 'If an idea is such a good idea why has no one done it?'. it is important to know whether the idea has already been implemented. If it has, the challenge is redefined to one of improving upon the idea, or choosing another issue, rather than starting from scratch.

For these reasons, the authors use case studies, personal stories and anecdotes throughout the module to illustrate where engineers have delivered remarkable solutions to sustainability challenges. In the references for each unit, additional case studies are also recommended. These are freely available on-line and are very useful to understand the current status of activities. Frequently referenced case study sources include:

- Engineers Australia - Environmental College (www.ieaust.org.au).
- Engineers Australia - Environmental Engineering Society (http://ees.ieaust.org.au/).
- Natural Advantage: Blueprint for A Sustainable Australia (www.acfonline.org.au).
- Natural Capitalism Inc (www.natcapinc.com).
- Natural Capitalism (www.natcap.org).
- Rocky Mountain Institute (www.rmi.org).
- Western Australia State Sustainability Strategy (www.sustainability.dpc.wa.gov.au).
- World Federation of Engineering Organisations (www.wfeo-comtech.org).

GRIFFITH UNIVERSITY TRIAL

Trial Structure

TNEP was invited by Griffith University's Environmental Engineering School, to trial a portion of the education module material within an existing first year environmental engineering course (delivered by the primary author of this paper). For the purpose of the trial, TNEP chose to cover four of the six units, during the first Australian teaching semester in May 2004. Unit 4 (Energy Use & Greening of Industry) and Unit 6 (Water & Waste) were not covered due to time constraints with the subject lecture availability. A video was presented in both weeks to provide a mix of teaching styles.

Actual enrolment in the Griffith first year subject is 50 students. Lecture attendance was estimated at 25 students in the first week and 35 to 40 students in the second week. The lower attendance rate in week 1 could have been because of the teaching week immediately following the Easter break.

Student and university feedback

A feedback form was given to each student in both teaching weeks, which comprised a total delivery time of 6 hours. The following points summarise key points provided in the feedback forms.

For most respondents the lecture material was new and there was enough content. Some respondents felt that there could have been more diagrams or examples to explain the terms presented. Just over half of the respondents felt that they understood the concepts and information provided. The lecturer had clarified to the students that they were not expected to understand all of the material as the intent of the lecture was to

familiarise them with terms and language.

All respondents felt that their understanding of sustainability had improved as a result of the lectures. Respondents were more familiar with terms and definitions presented in Unit 2, although they still all agreed that their understanding of the material had improved as a result of the lecture. The number of respondents who felt that their understanding had improved as a result of the third lecture was slightly less than for Unit 1 or 2 – one quarter of respondents only gained an increased understanding from some of the material. This could be attributed to the increase in student numbers in the second week – where students had not attended the first week of lectures, they may not have been able to grasp the content of the second week as well. It does not appear to have been due to the nature of the content, as most respondents indicated that at least some of the information was not new to them.

A higher proportion of respondents had heard at least some of the information presented in Unit 5(a) Urban Development and 5(b) Sustainable Transport before. This supports the decision to include both topics (at an introductory level) in the same unit.

Some respondents felt that there may have been too much information presented on some of the slides. Comments indicated that more discussions and less material on slides would have created a better learning environment. Some respondents felt that the lecturer went too fast through some material in both weeks. This is a result of discussions during the lecture, which then cut down on presentation time. The variety of material to cover in Week 2 was also more than in Week 1.

A representative collection of comments provided in the feedback form includes the following:

- "… starting to understand the role of enviro engineers. Nice presentation style - conversational. Maybe too much info - good info though!"
- "Very good and interesting"… "Fantastic"…. "Brilliant"… "Very good"
- "Very interesting and informative. Congratulations - most interesting lecture so far"
- "Too many words, not enough pictures. But still informative."
- "It was really, really good. When it was beginning to get dull, [the lecturer] made it interesting, therefore holding our attention."
- "Good to have a chance to talk" … "instead of looking at the slides."

Trial conclusions:

As a result of the trialing of the units, the following conclusions are made:

- The format and level of content provided within the units is pitched at the right level for first year environmental engineering students. Verbal feedback from the students and graduate of the environmental engineering course also visiting the lectures, indicated that the material could also be suitable for any general 'first year engineering' course.
- Students absorbed the concepts and material provided extremely quickly. From a position where most had not heard of the Brundtland report, by the end of the fourth lecture, discussions were informed, challenging and engaging as students drew on their own experience to form their own understanding of sustainability.
- The course lecturer considered it beneficial to include the material at this point in the course material. Students observed on a number of occasions that this information would assist them in their current and possibly future design assignments. They also commented a number of times that they felt inspired and energised by the material presented.

As a result of the trial, the trainers guide was modified to include a note to encourage the teacher/ facilitator to include less information on power-point material and discuss concepts and terms with the students. The trainers guide also recommended that students be provided with some handouts or notes to improve their retention of information and ability to engage with the material being presented. The guide recommended that teachers should allow 10 to 15 minutes of a lecture for discussion and questions, to ensure that the students don't feel overwhelmed by volume of material, and a short break between topics in Units 4 to 6.

NEXT STEPS

As modules are completed, the program authors intend to obtain international review of the content, to then revise the material as 'Version 2'. Panel members will be drawn from TNEP's existing network, and will comprise a mixture of professional body representatives as well as academia. Should the reader wish to be involved in reviewing this material or participating in the review of future modules, please contact the authors.

The Griffith university case study shows that the type of content presented is at least applicable for students with an interest in environmental engineering. Further trials are intended, to show that such material is also appropriate for students undertaking first year education in other engineering disciplines.

The program authors are also currently pursuing funding support to complete the remaining six modules (see **Figure 1**), which cover more complex ideas and technical information.

Engineers Australia, through the Environment College, is currently investigating opportunities to share this teaching information within Australia and potentially in South East Asia. The organisation is also exploring options for using this material, for example as a baseline for potential future accreditation possibilities.

CONCLUSIONS

One of the key purposes of the 2004 EESD conference is to help universities consider opportunities for educational programs. This paper has provided an example of an education module which can be used to help reform the current engineering education programs in Australia and possibly overseas, improving the quality of engineering curricula to include an early awareness of the role of engineering in the sustainability challenge.

The 2002 conference reflected that, "*problem oriented and function directed education and inter- and trans disciplinary approaches have to become elements of engineering courses*" (EESD, 2002). The format of this module has been developed to be as flexible as possible, to facilitate curricula changes for introducing sustainable development into all engineering degree courses. Future modules in the ESS Education Program will also address this need.

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