A Multi-Disciplinary Approach To Introducing Environmental-Sustainability Concepts Into A Civil Engineering Course

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***Abstract**: Over the last decade, debate around our ablity to design and live in a sustainable society has been growing more vigorous. Climate change, embodied energy, embodied water and global restraint on greenhouse gas emissions will mean that existing corporations, institutions, industries and businesses will undergo fundamental change and that the fresh engineering graduate will be employed in a rapidly adjusting workforce. Accordingly, a responsive University must adjust its courses to prepare their graduates. However, issues concerned with sustainability are not confined to any one or two disciplines, and they usually cut across two or more Faculties, a phenomenon that often proves difficult for Universities to contend with.*

Engineering courses are a natural nexus for issues involving science, business and society viewpoints, and are on the frontline of the cross- disciplinary issues. The typical response has been to design courses incorporating a suitable balance of science and business subjects, often with little direct links between them. In this paper, we discuss the ongoing development of the Civil engineering course at La Trobe University to encompass an increasingly inter-disciplinary outlook on sustainability.

***Keywords**: Civil engineering, sustainable infrastructure, environment, multi-discipline, climate and society.*

Introduction

For many years, human dominance of nature was unquestioned in the design and construction of modern infrastructure. Civil engineers produced modern infrastructure tuned to the prevailing climatic conditions. However, the work of a civil engineer can have a dramatic effect on the environment and growing public awareness of environmental controversies has added to the decline in image and status of the civil engineering profession (Beder, 1998). Furthermore, when the impact of such activities started to threaten businesses and the quality of life, the relevance of the environment to the civil engineer's work became paramount. There is now little debate that society's behaviour as a whole must change and with it the professional responsibilities of the civil engineer. If the climate changes, human society must adapt its designs and infrastructure. Climate change, embodied energy, embodied water and global restraint on greenhouse gas emissions will mean that the fresh engineering graduate will be employed in a rapidly adjusting workforce.

As early as the 1980s, Engineers Australia began to respond to the changing emphasis on environmental concerns and acknowledged the importance of environmental management to the profession. This included developing comprehensive policies (Engineers Australia, 2003) concerning the environment, sustainability and greenhouse gas emissions that are comparable to those of other

developed countries, and ensuring that University engineering courses, especially civil engineering courses, are reviewed and modernised to incorporate contemporary environmental expectations and pay due diligence to the concepts of environmental-sustainability.

Development of the Civil Engineering Course at La Trobe University, Bendigo

A major recommendation from the 2003 accreditation review of the civil engineering course was the need to integrate the environmental components of engineering over the four years of the course. This approach is consistent with the philosophy of Trevelyan (2008) who stated: "There is a need to bring serious consideration of human behaviour to the centre of engineering in engineering schools. While such a transformation of engineering education will not be easy, it might encourage many more young people to take up an engineering career with a much clearer idea of what lies ahead."

Accordingly, Civil Engineering at La Trobe University is developing a strong environmental-sustainability flavour throughout the undergraduate course, leading to a postgraduate course in sustainable infrastructure. In this paper, we shall only concern ourselves with the undergraduate course. We look in particular at the cornerstone and capstone subjects in the environmental-sustainability strand and discuss the features that differentiate them from conventional subjects.

Designing an Environmental Sustainability Strand

In keeping with accreditation standards, engineering courses are designed to incorporate a suitable balance of engineering, science and business subjects. However, in a typical university environment, it is difficult to ensure direct links are made between the subjects, and students are regularly required to acclimatise themselves to the subject coordinator's discipline-specific viewpoint. Environmental-sustainability issues don't have clear discipline boundaries, and in developing the Civil Engineering course it was considered important that we expose undergraduate students to the multi-disciplinary nature of the issues. Moreover, by the completion of their course, graduating engineers must be prepared to work within a complex and changing environment. Hence, we required a subject that provides them with skills specific to their role as civil engineers.

The current Civil Engineering course is shown in Figure 1. Subjects that incorporate environmental-sustainability issues are indicated with an asterisk. It should be stated that the course is designed such that there are a number of identifiable strands running through it, and subjects can contribute to more than one strand. The two subjects that we focus on in this paper are shown in bold. The first, *Climate, Sustainability and Society,* is multi-disciplinary and is a core subject in more than just the engineering course. The latter, *Sustainable Infrastructure* is an engineering-specific subject.

Climate, Sustainability and Society

Climate, Sustainability and Society is a subject being developed as part of a widespread curriculum reform across all of La Trobe University. One of the initiatives of the reform is to create a flagship first-year subject around the theme of climate and sustainability with the intention to eventually develop a sustainability theme throughout all levels of the university's educational processes. The initial first-year subject is being piloted on the regional campuses, and it is being taught for the first time in semester 2, 2009. Hence, at the time of writing, we are unable to present the results of the pilot. We focus instead on the intensions of the design of the subject and its suitability for undergraduate engineering students. Note that the subject was developed to address the issues of science, business and society, and as such it intentionally crosses disciplinary and Faculties boundaries.

Year	Semester 1	Semester 2
First	Calculus A Physics A Engineering Practice* Acc. For Management Decisions	Calculus B Mechanics of Solids **Climate, Sustainability and Society*** Engineering CAD
Second	Calculus C Civil Engineering Materials Structures 1 Surveying	Geomatics Engineering Group Research* Environmental Law* Hydraulics
Third	Numerical Mathematics Structures 2 Project Management Earth Science*	Hydraulic Engineering 1* Geotechnology A Civil Construction & Environment* Environmental Case Studies*
Fourth	Structures 3 Geotechnology B Hydraulic Engineering 2* **Sustainable Infrastructure***	Investigation Regional Engineering* Transport Engineering Structural Design

Figure 1: Civil Engineering course at Bendigo: Subjects with a specific environmental-sustainability focus are shown with an asterisk.

In 2009, the subject is core to students undertaking Civil Engineering and Business courses and an elective within Humanities, Science and Education. At Bendigo, the class is approximately 100 students, of which 35 are enrolled in Civil Engineering. Students are working in multi-disciplinary tutorial groups, and are required to undertake a case study in small mixed-disciplinary groups.

Within the classes, students are introduced to the concepts of climate and climate change, the known science, the uncertain science and the speculation, predictions and opinions that are abundant around the topic. They are confronted with the impact of society on the environment and of the changing environment on society, and exposed to three high-profile public speakers, nominally from science, economics and social science. There is no effort made to hide either 'alarmist' or 'sceptic' attitudes to climate change. Rather, we aim to make students conversant in the debate, and able to develop an appreciation of the complexity of the issue.

Each of the three disciplines, namely science, economics and social science, is granted one week in which to introduce their semantic space, the jargon, skills and ways of viewing the topic. After this, classes are presented via a mix of disciplines with an economist and environmental scientist discussing the value of water, and a sociologist and engineer contemplating the impact on society of engineering for a solution to water redistribution.

The stated outcomes for the subject are that students will:

- develop a vocabulary of contemporary definitions and theories relating to climate, sustainability and society,
- be able to synthesise provided information and deliver a reasoned view,
- recognise and use the semantic base from each of science, social science and economics,
- respond to contemporary news media and appropriate peer reviewed research literature to convincingly argue a point of view and convey arguments to peers,
- use a variety of resources to research a topic and construct an analysis relevant to a given context, and
- work in a team to develop a summary of this research, and to present it to peers.

The design of the subject aims to support the beginning undergraduate as they confront a major topical issue. For the civil engineering undergraduate, the subject is an entry point to the complex web of science and pseudo-science that pervades the media and the skills required to clarify and synthesise information before embarking on a solution to a complicated problem.

Sustainable Infrastructure

Sustainable Infrastructure was first taught in 2007 and complements the project-based learning stream consisting of *Engineering Practice, Engineering Group Research, Environmental Case Studies and Investigation,* where civil engineering is taught predominantly through project-based learning (Kilpatrick et. al. 2006). The details of the subject have been discussed previously (Russell, 2008). In this paper, we consider its place in the environmental-sustainability strand.

The importance of preparing undergraduate engineering students for a challenging and uncertain future cannot be underestimated as their working careers will be constrained by resource limitations and environmental issues. Beder (2006) states that "It would be far more environmentally beneficial to design processes and products that are ecological sustainable than attempt to find ways to repair and replace the lost environmental amenity and functions that are essential to life and wellbeing."

Students have already been exposed to the changing future in earlier subjects. By their final year, students are preparing to enter the workforce. They require a subject that takes them beyond the traditional zone of calculation and predictability. Hence, the goal of *Sustainable Infrastructure* is to prepare students to address the complex real-world problems facing civil engineers.

In this subject, students are required to question the methodology and archetypes that had formed the basis of much of their education and training. The intention is that students will appreciate that physically sustainable infrastructure originates within the concepts of the human mind. The subject requires students to consider a major contemporary organisation and anticipate where that organisation will be in 2020 after addressing the impacts of climate change and possible energy shortages. Each such organisation will have a significant investment in existing infrastructure, client expectations and significant plans for future infrastructure development taking into account climate and energy issues. Half of the assessment for the subject is based on a group 'Futuristic Report' that predicts where that particular organisation could be in the year 2020, with particular attention paid to the civil engineering infrastructure components (Russell, 2008).

The subject takes as its starting point Beder's (2006) six major principles, namely, 'ecological sustainability', 'the polluter pays principle', 'the precautionary principle', 'equity', 'human rights' and 'public participation', and it takes students through a process of conceiving, designing, constructing, operating and maintaining sustainable infrastructure. Students acquire much of their understanding from visiting a number of regional organisations. During these visits, engineering representatives of the organisations provide information of the organisations based on a template of key issues. These issues include:

- the vision, structure of the organisation and its responsibilities,
- skill base, scope of work, asset register,
- operations and maintenance, energy costs, life cycle of assets,
- major projects,
- threats and solutions, and
- the impact of sustainability requirements on current and future activities.

Students' Response to Sustainable Infrastructure

The Futuristic Reports provide evidence of how students have incorporated elements of sustainability in infrastructure planning. Extracts from the conclusions of four of these reports are as follows.

Sustainable Buildings "The fundamental driver for change to our building stock is climate change, which has its roots in carbon emissions; another driver is the availability of fresh water. Sustainable buildings have the potential to significantly cut our energy use and water consumption. This reality is the crossroads in a sense; society will either flourish under the new paradigms of thinking or perish. Sustainable design and construction of buildings will have to be adopted to prevent climate change, and large social change will result. This process will take a long time; however the outlook for the sustainable construction industry in 2020 is positive. Cities will be inundated with sustainable buildings and homes, and as a result our carbon emissions and water consumption will be a fraction of

the current levels. The technology is not new; what is new is bringing them together and making it happen. This is the challenge we face."

Sustainable Infrastructure Goulburn Murray Water 2020 "For each of the different forecasts, there are different possible outcomes. Not all of them are good, but each will see the company changing in its thinking, procedures and the way in which GMW will conduct its business. Some of the predictions will see GMW operating a prosperous and vibrant business while others will see hard times ahead for a company with no service to provide or providing services to a different customer base. GMW needs to consider all of the future business influences presented in this report, to enable the company to plan ahead and be prepared for any situation that may arise."

Rail in Victoria: Threats to its viability and a vision for its sustainability beyond 2020 "All of the evidence indicates that government should take responsibility of managing the rail network, and shift the majority of transport funding from road to rail. This investment increase in rail infrastructure would ensure that the network is better able to meet the requirements of the consumer and, with rail being the most environmentally sustainable transport option for the future, would ensure its economical sustainability and best meet the State government's emission reduction objectives."

VicRoads 2020 "The implementation of the various sustainability initiatives discussed in this report will have major implications on the methods utilised during civil engineering activities. With the onset of 2020, the civil engineering discipline will be more and more intertwined with the environmental engineering. Already universities such as La Trobe in Bendigo are promoting a 'green thumb' in their graduates. The general consensus is that in the current sustainability climate, the effective and efficient design and construction of roads and bridges cannot be achieved without due consideration of the environment and application of effective sustainability initiatives. A design and construction civil engineer in 2020 without these skills will be virtually unemployable."

Student feedback for this subject has been consistently positive (Russell 2008). Students have noted that the subject connects theory to practice in a hands-on way and made them think outside the box. They also noted that the subject gave them the capacity to tackle bigger real-world problems and to see problem-solving in action through the industry presentations.

Surveys of graduating students provided the following insights in their experiences of the subject matter. Some typical responses were as follows.

- "Opened up a new perspective of looking at infrastructure, and why engineers should be familiar with sustainable issues."
- "Looking at the importance of sustainability in engineering future projects."
- "The inside view of different corporations in their effort to make Victoria more sustainable towards the future."

The success of *Sustainable Infrastructure* combined with the shortage of civil engineers in Australia has led to the development of two new postgraduate degrees in Sustainable Infrastructure that are planned to commence in semester 1, 2010.

Conclusions

The increased environmental-sustainability component incorporated as a strand in the Civil Engineering course at the Bendigo campus of La Trobe University has satisfied the accreditation expectations of addressing environmental issues as they relate to the civil engineering. The new first-year subject is exposing undergraduates to a multi-disciplinary approach to climate and sustainability, and assisting them to understand the role of the civil engineer in influencing and transforming modern society. The final-year subject requires students to use a multi-disciplinary approach when considering the future viability of engineering projects and organisations. This enables graduates to work in a rapidly changing environment, facing issues of climate change, resource limitation and embodied energy and water. In this way, the Civil Engineering course at Bendigo continues to provide graduate who are equipped to meet emerging future challenges.

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