Engineering education: Preparation for future leadership roles

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Abstract: *The ever-increasing complexity of a rapidly changing world demands that leadership responsibility is bestowed on leadership teams rather than relying on individual leadership. Engineering courses can respond to these changes by moving the emphasis from providing a tool-kit professional training for prospective engineers to one that expands their attributes to include an appreciation of the importance of the environment, sustainability issues and being competent to lead effectively in an area of speciality as a team participant. This paper discusses the fundamental transformation of the Bachelor of Civil Engineering course at La Trobe University, Bendigo over the last ten years to meet accreditation requirements and develop leadership skills. This has been achieved through extending professional knowledge-based learning and fostering an awareness of the global challenges ahead.*

Introduction

Long gone are the days when statics, dynamics, rivets and steam ushered in a predictable promising future. Now, in the beginning of the 21st century, environmental and sustainability concerns have become a major focus of developed industrialised countries. Accordingly, professional graduates from most spheres must be competent to deal with such complex issues. This requirement is particularly acute for engineering education, as engineering underpins our modern way of life, and engineering graduates will play a major role in shaping the future. This paper discusses the evolution of team leadership skills, and the adaptation of the civil engineering curriculum in recognition of the vastly different tool-kit that a graduate must carry into the workforce. The tool-kit must prepare the graduate not only to confront the environmental and sustainability challenges ahead, but also to provide solutions to these challenges.

Changing Demands on the Engineering Curriculum

The traditional engineering tool-kit, with its heavy emphasis on technical content, equipped graduates to serve a vital role in the 20th century. Until approximately the 1980s, most graduate engineers in the State of Victoria commenced their careers in large government engineering establishments, such as Melbourne Metropolitan Board of Works, Public Works Department, State Rivers and Water Supply Commission, State Electricity Commission of Victoria, Country Roads Board, and Railways and Tramway Boards. These organisations preferred graduates with a good grounding in engineering basics as a starting point for their induction into the culture of their particular organisation. Conformity, continuity and succession were deemed vital requirements for the organisation to deliver

its legislative responsibilities. To this end, training and mentoring of a graduate for the first five years in the organisation was considered in most cases near mandatory. This period was also characterised by engineering employment stability. Each organisation had many levels of control, and leadership was from the top-down similar to the military model.

The 1980s and 1990s saw all the above organisations transformed with the majority of their engineering work, which was considerable, outsourced to consultants and contractors who operated in a competitive environment and purportedly delivered infrastructure more efficiently and at a lower cost. One of the most significant outcomes from this transformation was that consultants, and particularly contractors, did not want to incur the additional overheads of mentoring and developing graduate engineers. Contractors wanted their graduates to 'hit the ground running', and consultants were forced to do their mentoring 'on the run'. This period was also characterised by mobility in employment. Consultants and contractors, nearly by definition, are organizationally flat, and their leadership is responsive to changing circumstances to survive. Horizons are short and the cycle of completing the last job, working on the current job and writing proposals and tenders for the next job is endless.

The common thread to professional engineering practice is teamwork. Whether it is the type of teamwork of a very large government organisation or that required by a consultant or contractor, teamwork is the vital requirement for delivering quality projects on time and on budget. More recently, the increasing levels of complexity have required structured teams with individual teamwork leaders working under a project manager. Most general managers and chief executive officers of large organisations are the executives of leadership teams. Coincident with the outsourcing of infrastructure works by government and the added level of complexity available by ready access to computing power comes the information revolution, and the growing awareness of environmental and sustainability issues.

The changing demands on the engineering curriculum are the new challenges of the 21st century. Undergraduates must be prepared as participants and leaders in this new environment. Some of these challenges include:

1. Climate change. The uncertainties associated with regional and global climate change have the potential to cause economic and social disruptions and have implications for existing and future infrastructure on which society depends.

2. Finite resources. The Western development in the 19th and 20th centuries was underpinned by cheap fossil fuel. The era of cheap energy appears to be coming to an end, and is being accelerated by the expectations of the BRIC nations (Brazil, Russia, India and China).

3. Carbon Economy. The introduction of a 'price for carbon' would influence all transactions in the world, and it will have a marked impact on many commonly-used construction materials, such as cement, aluminium, steel and bitumen. An over-dependence on coal is advancing the need for the development of mass renewable energy sources together with a significant re-design of the current economy.

4. Population growth. The expectation of a 'western' lifestyle for everyone makes considerable demands on the world's resources, and it may require the transformation of society's expectations on limits to growth.

It was Beder in the 1990s who publically focussed Australian engineering thinking on the issues of the environment and sustainability (Beder, 1993, 1998). These two issues were taken up by Engineers Australia, and they transformed conventional engineering consciousness to include the environmental and sustainability issues as underpinning tenets of all engineering activities in Australia (Engineers Australia, 2003). An ongoing part of this transformation has occurred through Engineers Australia's

course accreditation process. It is of interest to note that these two actions in themselves are examples of individual leadership by Beder and team leadership by Engineers Australia.

In the foreword and executive summary of *Engineers for the Future – addressing the supply and quality of Australian engineering graduates for the 21st century* (ACED, 2008) it was stated "The study examined the state of the engineering education system, with respect to its ability to meet future challenges…and reports on the stakeholders' concerns…that the balance of subjects with current engineering curriculum are not adequately matched to graduates' and industry's current and future needs." In "A Vision for Australian Education" (ibid, 2008) it was further stated "Graduates will make positive contributions to their profession. Many will work towards solving significant challenges such as global sustainability, water and energy supply. The education system provides a platform for launching graduates into influential leadership roles in engineering and other fields."

In this paper, we consider the evolution of the civil engineering curriculum at La Trobe University, Bendigo over a ten year period, as it seeks to meet both the changing needs of employers, who contractually respond to the prevailing environmental and sustainability policies, and the responsibility of the university to prepare engineering students for their professional life. The broadening of their learning is intended to produce graduates who are able to deal with current critical issues.

Subjects in the Bachelor of Civil Engineering Course at La Trobe, Bendigo

A comparison of the subjects in the Bachelor of Civil Engineering course at La Trobe University, Bendigo over the last ten years is shown in Table 1. The seven new subjects in the 2010 curriculum are shown in bold.

The systemic system changes to the curriculum are as follows.

1. Introduction of *Group Research*.
2. The vertical integration of an Environmental Stream throughout the course. These subjects are shown in italic.
3. The vertical integration of a Project Learning Stream throughout the course. These subjects are shown underlined.
4. The recent inclusion of book-end subjects, one in first year and one in fourth year, that specifically address the new challenges of the 21st century.

In 2000, *Group Research* was introduced into the first year of the engineering course. This subject was successfully modelled on a first-year science degree subject at La Trobe University (Legge et al, 1999), which was founded on problem-orientated group project work originating at Roskilde and Aalborg universities in Denmark. *Group Research* later evolved into *Engineering Practice,* where in first year "students gain an exposure to the broad range of principles and practices of the professional engineer, whilst at the same time they are introduced to a range of academic assistance and initiated into the skills of working in a group." (Kilpatrick et al, 2006).

The Accreditation Board of Engineers Australia conducted a review of the course in 2003. The main recommendation was for there to be more emphasis on environmental issues over the four years of the course. Consequently, four subjects, *Environmental Science* (later replaced by *Climate, Sustainability and Society*), *Environmental Law*, *Environmental Case Studies* and *Sustainable Infrastructure* were vertically integrated into an Environmental Stream. The successful experience with *Engineering Practice* led to the development of a Project Learning Stream consisting of four subjects, namely *Engineering Practice, Engineering Group Research, Environmental Case Studies and Investigation* (Kilpatrick et al, 2006).

By 2007, the Civil Engineering course had viable Environmental and Project Learning Streams, and was positioned to educate students for team leadership roles.

Table 1: Comparison of 2000 curriculum (left) and 2010 curriculum (right). Different units in 2010 are shown in bold.

YEAR	2001	YEAR	2010
First		First	
Semester 1	Calculus 1 Physic 1A General Chemistry Engineering CAD	Semester 1	Calculus A Physics A **Engineering Practice** Acc. For Management Decisions
Semester 2	Calculus 2 Mechanics of Solids IT Fundamentals Communications	Semester 2	Calculus B Mechanics of Solids ***Climate Sustainability & Society*** Engineering CAD
Second		Second	
Semester 1	Calculus 3 Civil Engineering Materials Organisational Behaviour Surveying	Semester 1	Calculus C Civil Engineering Materials Structures 1 Surveying
Semester 2	Probability Environmental Science Structures 1 Hydraulics	Semester 2	Geomatics **Engineering Group Research** ***Environmental Law*** Hydraulics
Third		Third	
Semester 1	Acc. for Management Decisions Earth Science Numerical Mathematics Structures 2	Semester 1	Numerical Mathematics Structures 2 Project Management Earth Science
Semester 2	Hydraulic Engineering 1 Geotechnology 1 Civil Construction Geomatics	Semester 2	Hydraulic Engineering 1 Geotechnology A Civil Construction & Environment ***Environmental Case-Studies***
Fourth		Fourth	
Semester 1	Elective Geotechnology 2 Hydraulic Engineering 2 Project Management	Semester 1	Structures 3 Geotechnology B Hydraulic Engineering 2 ***Sustainable Infrastructure***
Semester 2	Investigation Structures 3 Transport Engineering Structural Design	Semester 2	Investigation ***Regional Engineering*** Transport Engineering Structural Design

The Book-End Subjects

In 2007 and 2009, two book-end subjects were introduced into the course, namely *Climate, Sustainability and Society* and *Sustainable Infrastructure. Climate, Sustainability and Society* is a multi-disciplinary subject that introduces first-year students to the challenges of the 21st century, and

deals with the subject matter in an open, enquiring way before embarking on a solution to a complicated problem. *Sustainable Infrastructure,* taught solely to civil engineers, empowers the final year students to apply their acquired skills and insights into transforming existing and proposed infrastructure into infrastructure more aligned with the emerging challenges. Both subjects are briefly discussed below.

Climate, Sustainability and Society

The development of *Climate, Sustainability and Society* was in part a response to widespread curriculum reform across La Trobe University. The subject was created as a flagship first-year subject around the theme of climate and sustainability. This will form the basis for further development of a sustainability theme throughout all levels of the university's educational processes. Within the subject, students are introduced to the concepts of climate and climate change, and the consequences of human behaviour. Discussions include the known science, the uncertain science and the speculation, predictions and opinions that are abundant around the topic. Students are confronted with the impact of society on the environment and of the changing environment on society, and are exposed to three high-profile public speakers from science, economics and social science. The subject aims to make students conversant in the debate, and able to develop an appreciation of the complexity of the issues (Russell et al, 2009).

The subject requires students to address the concerns of a community group within a given local government area. Students prepare a report that outlines the predicted future climate in the region, together with the certainty of their predictions and the impact such changes may have on the community's economy, ecosystems and social structures.

Sustainable Infrastructure

Sustainable Infrastructure was first taught in 2007 and it complements the Project Learning Stream consisting of *Engineering Practice, Engineering Group Research, Environmental Case Studies and Investigation* (Kilpatrick et al, 2006). The subject is under-pinned by the statement "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 well-being." (Beder, 2006).

In this subject, students are challenged to question the methodology and archetypes that formed the basis of much of the education of their predecessors. Within the subject, teams of students consider a major contemporary organisation and anticipate where that organisation will be in 2020, while addressing the impacts of climate change and possible energy shortages. A major piece of assessment involves a 'futuristic report' that considers the organisation's investment in existing infrastructure, client expectations and significant plans for future infrastructure development. A full account of this subject is given in Russell, 2008.

The use of project learning tools through many subjects of the course and the vertically integrated theme of environmental and sustainability issues are essential parts for developing leadership skills. In 2010, each of the reports displayed originality and leadership capability. Feedback on the subject has been consistently positive, and students were pleased to forward their reports to the corporation leaders.

Development of Leadership Skills

The changes in the course have enabled a logical and progressive development of leadership skills that embrace the current focus on environmental and sustainability issues. In general, the earlier 'tool-box' civil engineering courses required a lone effort by the student in the acquisition of a standard set of

engineering skills, while inherent leadership qualities would be nurtured by the paternalistic organisations referred to earlier. In the current Civil Engineering course, the emphasis on teamwork, environment and sustainability equips students with contemporary behaviour patterns and solutions to challenging issues that are prerequisites for leadership roles in a modern society. This subtle growth in the consciousness of students, including those whose leadership leanings are low, prepares them for encounters with engineering leaders in sustainable infrastructure.

For example, final-year students are exposed to leaders in strategic positions in State government corporations, such as transport, energy, buildings and water. Many of these professional leaders delight in the engagement with students and in outlining the achievements and limitations of their organisations in addressing the current and future challenges. Such opportunities provide students with a personal benchmark of their skills and knowledge on the issues and solutions presented by the leaders and this experience empowers students as change agents.

In the students' final-year major projects, they are expected to demonstrate complex leadership skills that are consistent with the expectations of industry. For example, through the encouragement of the Secretary of the Victorian Government Department of Transport, two students, one confident and one whose leadership aspirations were low, won a national award for their project 'A Proposed Orbital Transport System for Melbourne'. This project proposed a new public transport system to help Melbourne move towards a more sustainable future (Lorena and Mulholland, 2009).

The success of La Trobe's evolving civil engineering curriculum has been demonstrated through the success rates of graduates in gaining employment in a competitive marketing and the positive feedback received from their employers.

Concluding Remarks

The Civil Engineering course at La Trobe University, Bendigo has undergone a fundamental transformation in the last ten years from a traditional took-kit course for prospective young engineers to one that satisfies accreditation requirements and prepares students for leadership roles in the 21st century. The evolution of the course is a work in progress, and future changes will be made to the course to ensure that it continues to produce graduates who can work in an ever-changing and challenging environment.

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