Towards sustainable engineering at RMIT University

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Abstract: *This paper investigates options for incorporating 'global sustainability' matters into RMIT University's undergraduate engineering degree programs. The project has been supported by the Institute for Global Sustainability at RMIT and the Faculty of Engineering. It reports on findings from interviews conducted with a number of employer representatives, on capabilities relating to sustainability that they saw as desirable in engineering graduates. On the basis of interviews and the Institution of Engineers Australia's engineering graduate attributes, a number of graduate capabilities relating to sustainability are recommended for RMIT engineering degrees. We propose that three thematic streams be run over the four-year engineering programs to develop these sustainability capabilities in graduate engineers. These themes are sustainable engineering principles and practice, social shaping and assessment of technology, and sustainable design.*

Keywords: *sustainability, engineering graduate capabilities, social shaping and assessment of technology*

Introduction

There is increasing interest in sustainability within governments in Australia at federal, state and local levels. In the private sector too, more and more corporations are adopting sustainability as a key objective of corporate governance, and practicing triple bottom line – social, environmental and financial – accounting practices in reporting to their boards, shareholders and the general public. The business case for sustainability is becoming increasingly accepted in the corporate world. Universities need to ensure that their graduates are well equipped to handle these demands.

This paper has been prepared as the primary outcome of a three-month project to investigate options and to assemble relevant information and other resources for incorporating 'global sustainability' matters into RMIT University's undergraduate engineering degree programs. The project is a component of the Faculty of Engineering's Program Renewal process and has been supported by the Institute for Global Sustainability at RMIT. The paper draws on two discussion forums held for interested staff from the Faculty of Engineering at RMIT, and interviews with representatives of several organisations that have addressed the question of desired capabilities of engineering graduates relating to sustainability.

Previous Work on Sustainable Engineering Education

There is a growing body of work in Australia and internationally on incorporating sustainability into education generally and into engineering education in particular. This work has been reviewed by Carew and Mitchell (2001). Here we briefly examine some examples.

The University of Technology Sydney has been working since 1998 to incorporate sustainability-related content, understanding and skills into its engineering degrees. The Institute of Environmental Studies at the University of New South Wales (2002) has produced a booklet offering broad assistance to academics in teaching global sustainability matters, focusing on how to engage students in activities and thinking that impact on sustainability. At RMIT, Roger Hadgraft (2002) advocated "inclusive teaching that recognises four learning styles and stages: understanding the problem in its context, theory, application and new possibilities". He suggests more emphasis on project-based and problem-based learning.

The Institution of Engineers Australia in collaboration with CSIRO, the Barton Group and a number of other organisations initiated the "Natural Edge Project" in 2002 to develop a 250-300 page resource book and associated web site to be entitled *Towards a Sustainable Future: Business Opportunities, Innovation and Governance in the 21st Century*. The project seeks to examine key sustainability issues and ways forward from a business/innovation perspective, with a focus on the most cost-effective best practice in the Asia Pacific.

Sustainability Capabilities Sought by Employers

Interviews

Interviews were conducted with eight senior personnel working in areas dealing with sustainability and sustainable development in industry and government, to gain an indication of the capabilities relating to sustainability that they saw as desirable in engineering graduates. Views were also obtained from a presentation by a senior manager of a large company to the second Sustainable Engineering Forum at RMIT convened in November 2002. Interviewees were selected using the RMIT Institute for Global Sustainability's list of industry contacts. All responded enthusiastically to the request to participate in the project. Of the nine people whose views were canvassed, six worked for large private corporations, one for CSIRO, one for a State Government department, and one for a State Government agency. Collectively their experience encompassed the mining, petroleum and associated processing industries, manufacturing industry, transport, energy and water supply, and forestry.

The group interviewed was small, and hence was not representative of the entire population of organisations employing graduate engineers. Particular limitations were the following:

- Resource-based industries were strongly represented;
- Only two representatives from manufacturing were interviewed;
- No consulting engineers were interviewed;
- All representatives were from large corporations and large government departments, and none from medium and smaller organisations;
- Only senior personnel in the organisations concerned were interviewed.

Nevertheless, much useful qualitative information and ideas on desirable 'sustainability' capabilities in engineering graduates were obtained from the interviewees. The main points to

emerge from the survey are described next. In must be stressed that because the research is of a qualitative nature, no quantitative conclusions should be drawn from the data presented.

Main trends affecting response to sustainability

All interviewees regarded sustainability as an issue of considerable and growing importance, and one that should receive prominent coverage in all undergraduate engineering programs. They identified trends in industry and the broader environment that will be critical in shaping the way sustainability issues are understood and dealt with over the next five years.

A key trend alluded to was pressure from the public, and particular communities adversely affected by certain projects or technologies, for social, environmental and wider economic impacts of these developments to be fully considered in company and governmental decision-making (mentioned by 8 out of 9 interviewees). Those working in the mining, minerals processing and energy industries referred to the need to deal sensitively with the issues raised by indigenous communities and other local communities impacted by particular projects.

Most interviewees also noted changes within their organisations, including:

- making sustainable development – embracing economic, environmental and social dimensions – a central part of a company's mission (mentioned by 4 interviewees);
- responding to the climate change issue by reducing greenhouse gas emissions and shifting to renewable energy sources (4 interviewees); and
- taking greater responsibility for stewardship of a resource or product throughout its lifecycle even if they are directly involved in just part of that lifecycle (4 interviewees).

Desirable organisational attributes to deal with sustainability

Organisational attributes to deal successfully with the sustainability issue that were most frequently nominated by interviews were:

- to engage sensitively and constructively with the communities in which an organisation operates in order to secure their acceptance of a project (7 interviewees);
- to practice sustainability as an integral part of being a good corporate citizen with a good reputation with customers and the general community (5 interviewees).

Sustainability initiatives being taken

Initiatives being taken by organisations in response to the challenge of sustainability and sustainable development included:

- Adoption of company policies with sustainability objectives – social, environmental and economic – and performance targets relating to these objectives that are publicly reported;
- Calculating and trying to improve the ecological footprint of a company;
- Programs to raise staff awareness of and skills in dealing with sustainability;
- Addressing social, environmental and broader economic (as opposed to internal company financial) issues right from the conceptual, design and planning stages of a project;
- Designing products that contribute to sustainability;
- Introducing new or reengineering existing processes to achieve greater sustainability;
- New processes to consult local communities on developments that affect them;
- Introduction and implementation of environmental management systems.

Desirable engineering graduate capabilities relating to sustainability?

The central question of the interviews was the following:

> *Reflecting on the discussion so far, what values, understanding, knowledge and skills will forthcoming graduate engineers require to assist their organisation deal successfully with sustainability/sustainable development?*

In response, the graduate capabilities relating to sustainability most commonly referred to by the interviewees were as follows:

- Ability to assess and evaluate the importance of social, environmental and economic (as opposed to simply internal financial) impacts of a project, technological development, new process or product, using a holistic systems approach, with a scope encompassing all communities and natural resources affected. (All interviewees mentioned this to some degree.) Specific techniques mentioned included use of triple bottom line, lifecycle costing, determination of ecological footprints, and environmental impact assessment.
- The skills to communicate, listen, negotiate, resolve conflicts and work harmoniously with communities affected by the activities of the organisation. (Mentioned by 8 interviewees.) Such communities need to include indigenous communities both in Australia and possibly developing countries in which Australian-based organisations operate. Hence, basic understanding of and skills in cross-cultural communication and relationships are needed.
- Ability to engage in 'sustainable design' – of production processes, products, plants and other facilities, technologies, and projects – so that social, environmental and economic sustainability criteria guide the design process right from outset, and the maximal sustainability outcomes are obtained. (All interviewees mentioned this.) A number of the interviewees referred in particular to the need to encourage engineering graduates to "think outside the square", to have the confidence to innovate and depart from the traditional technical solution pathways, in the sustainable design process.
- Understanding of, and personal commitment to, the principles of sustainability and sustainable development, including the ethical foundations of these concepts, and the ability to exercise considered judgments based on these principles in real-life situations. (Mentioned by 6 interviewees.)

In addition, more specific 'sustainability' capabilities were mentioned in passing by some interviewees as desirable: knowledge and ability to develop environmental management systems, understanding of the principles of industrial ecology, cleaner production, and expertise in renewable energy technologies. However, the foregoing are clearly just a small sample of a much larger complete listing. Within each engineering discipline there are many specific capabilities relating to sustainability that are desirable for graduates to possess.

Deficiencies in graduates relating to sustainability

The interviewees referred to a number of deficiencies in graduate engineers (pertaining to sustainability but also applying more generally). These included:

- A too narrow focus on technical solutions, with consequent failure to take adequate account of social, environmental and economic/commercial implications, particularly at the early stages of a project. In other words, they often 'do not see the bigger picture'. They tend to be project-centred rather than whole-system oriented.
- Reliance on standard solutions to standard problems, and lack of confidence in taking new paths that may lead to innovation and major rather than incremental gains in sustainability.

- Insufficient skills in communicating concisely, clearly and persuasively to senior management or a non-technical audience, to gain approval and support for their proposals. One interviewee made the interesting point that engineers do not spend enough time on the front end of their report, the executive summary and recommendation for action, which is the critical part that senior management will actually read and use in deciding whether to approve the recommendation. They tend to be more concerned that the report 'passes the weight test' and is packed full of facts and figures.

Suggested 'sustainable engineering' learning activities

The interviewees were asked to suggest some learning activities that could help undergraduate engineers develop the sustainability capabilities. Some of their responses included:

- Get students out of the university, talking to practitioners, the community (including indigenous communities), seeing what is actually being done.
- Presentations from representatives from industry, environmental organisations, indigenous peoples' organisations.
- Use, case studies of actual projects showing technical, social, environmental and economic problems arose and how they were dealt with. Ask students to develop plan of action to see that these problems did not occur in the next project of this kind. Encourage the search for innovative solutions. Develop case studies in collaboration with companies or government organisations that work in this area. Involve company, government and/or community representatives in critiquing the solutions proposed by students.
- Student involvement in team projects – some involving students from non-engineering disciplines – to develop innovative solutions to problems relating to sustainability, with the aim of maximising the social, environmental and economic outcomes in a manner that was acceptable to the communities affected. The ability to work effectively in a team environment was a common theme in the interviewees' responses.

The IEAust Graduate Attributes and Sustainability

The relevance of sustainability in engineering education has been recognised for some time. The Institution of Engineers Australia (IEAust) published the findings of an extensive review of the future of engineering education in Australia (IEAust, 1996). The review identified that successful graduate engineers would increasingly require both in-depth technical competence and a broader set of attributes or capabilities that included sustainability. The IEAust now requires that engineering graduates develop the following generic attributes:

a) ability to apply knowledge of basic science and engineering fundamentals;
b) ability to communicate effectively, not only with engineers but also with the community at large;
c) in-depth technical competence in at least one engineering discipline;
d) ability to undertake problem identification, formulation and solution;
e) ability to utilise a systems approach to design and operational performance;
f) ability to function effectively as an individual and in multi-disciplinary and multi-cultural teams, with the capacity to be a leader or manager as well as an effective team member;
g) understanding of the social, cultural, global and environmental responsibilities of the professional engineer, and the need for sustainable development;
h) understanding of the principles of sustainable design and development;
i) understanding of professional and ethical responsibilities and commitment to them; and
j) expectation of the need to undertake lifelong learning, and capacity to do so. (IEAust, 2002, p. 14)

Clearly all of these attributes embody sustainability aspects to some degree, while attributes (g) and (h) have a particularly strong connection to sustainability. As part of its BEng Program Renewal Project, RMIT University has elaborated upon each of these engineering

capabilities, in reference to engineering education in the RMIT context. We have ourselves further elaborated upon the sustainability aspects of each of these capabilities. For space reasons, this work is not included here, but is fully described in Andrews (2003).

Engineering Graduate Capabilities Relating to Sustainability

On the basis of the engineering graduate capabilities proposed by the employer representatives interviewed (section 3), and the sustainability aspects of the Institution of Engineers Australia's required engineering graduate attributes (section 4), we have recommended the following highest-level graduate capabilities relating to sustainability are recommended for RMIT engineering degrees:

- Understanding of, and commitment to, the principles of sustainability and sustainable development, including the ethical foundations of these concepts, and the ability to exercise considered judgments based on these principles in real-life situations.
- Ability to assess and evaluate the importance of social, environmental and economic (as opposed to simply internal financial) impacts of a project, technological development, new process or product, using a holistic systems approach, with a scope encompassing all communities and natural resources affected.
- The skills to communicate, listen, negotiate, resolve conflicts and work harmoniously with impacted communities.
- Ability to engage in 'sustainable design' – of production processes, products, plants and other facilities, technologies, and projects – so that social, environmental and economic sustainability criteria guide the design process right from outset, and the maximal sustainability outcomes are obtained.

Sustainability and Engineering Program Structure

Overall Architecture

It is proposed that three thematic streams be run over the four-year engineering programs to develop the proposed sustainability capabilities in graduate engineers:

- *Sustainable engineering principles and practice*, which would address directly the first sustainability capability, 'understanding of and commitment to sustainability principles', including their ethical foundations, the meanings of sustainability and sustainable development, and the use of these principles in practical decision making and judgments.
- *Social shaping and assessment of technology*, which would focus on the social (including economic, political, organisational governance, and cultural) processes by which decisions on technological development are made; the various techniques available for integrated social, environmental and economic assessment of technologies and projects; the business case for sustainability; and involvement of affected communities in impact assessment. This stream would develop both the second ('social, environmental and economic assessment') and third ('communication and negotiation skills') sustainability capabilities.
- *Sustainable design*, relating mainly to the fourth capability, 'design from the outset to achieve optimal and balanced social, environmental and economic outcomes', but also providing further opportunity to develop the third capability by engaging potentially affected social groups in the design process.

A significant portion of the total content of each of these three sustainable engineering streams will be applicable to all engineering programs, since they deal with principles (ethical and technical), understanding and knowledge, and skills and techniques relating to

sustainability that are desirable for all engineers to have. The remainder of the content in each stream will preferably be specific to the various engineering programs, so that the practical relevance of the content to their chosen discipline is manifest to students. Hence there would be clear advantages in terms of ensuring consistency in curriculum, and economies of scale in curriculum development, if the portions of the three streams applying to all engineering programs are developed as a common component.

A considerable part of the first two proposed sustainable engineering streams in particular – 'sustainable engineering principles and practice' and 'social shaping and assessment of technology' – can be seen as providing the broader context in which professional engineers operate, and developing in them the values, understanding, knowledge and skills they will need to perform their professional roles successfully. The third stream, 'sustainable design', however, is more appropriately located as part of the core of each engineering program, given that it will involve innovative technical design and planning activities to achieve beneficial social, environmental and economic outcomes.

In the following three sections we sketch a possible scope of each of the proposed sustainable engineering streams. In describing these scopes, we are more concerned here with giving an idea of what the streams will cover, than with the way in which they will be taught and learnt.

Sustainable Engineering Principles and Practice

The objectives of this stream would be to:

- Explain why many current trends in Australia and globally are unsustainable socially, environmentally, and economically, including from perspective of individual businesses;
- Provide students with an understanding and knowledge of the principles of sustainability and sustainable development;
- Stimulate debate among students as to what sustainability and sustainable development mean, and what should be done to achieve these aims, so that they develop their own goals and commitments to action in these areas;
- Create learning situations in which students gain practical experience in making decisions and judgments based on sustainability principles;
- Demonstrate that sustainable principles and practice are integral to the role of the engineer, to good corporate governance, and to best business practice and outcomes.

Social Shaping and Assessment of Technology

The objectives of the social shaping and assessment of technology stream would be to:

- Provide students with an understanding of the social processes that 'shape' the development and deployment of technologies;
- Explore the history of selected technologies and projects to discover why certain unsustainable impacts arose, how they might have been avoided, and the lessons that might be learnt for effective and responsible corporate governance in the future;
- Familiarise students with a variety of techniques to assess impacts of technological developments and projects in social, environmental and economic terms, using a holistic systems approach;
- Demonstrate how affected communities can be involved in the impact assessment and decision-making processes;
- Develop in students the skills to communicate, listen, negotiate, identify and resolve conflicts, and work harmoniously with impacted communities;

- Show how good corporate governance that involves impacted social groups in shaping a new technology or project can optimise social, environmental and economic outcomes, including the bottom-line financial performance of the organisation concerned.

Sustainable Design

The objectives of this stream would be to:

- Provide students with an understanding of the principles of sustainable engineering design and the opportunities for innovation these principles create;
- Allow students to gain practical experience in designing technologies and planning projects to optimise social, environmental and economic outcomes, and enhance overall business and organisational performance;
- Introduce students to design processes that integrate the analysis of social, environmental and economic impacts, and communication with affected social groups, into all stages from initial concept, to implementation and operation, and recycle and reuse.

Recommendations

On the basis of the research and consultation conducted within this project, the following provisional recommendations have been presented for further discussion by selected program teams during the Engineering Program Renewal Process in RMIT during 2003:

- Make 'Sustainable engineering', in the sense of using technical engineering expertise to achieve beneficial and balanced social, environmental and economic outcomes, and hence contributing to sustainable development, a central theme in all RMIT undergraduate engineering programs.
- Present sustainable engineering in three thematic streams over the four-year programs: Sustainable engineering principles and practice; Social shaping and assessment of technology; and Sustainable design.
- Embed sustainability principles, understanding, knowledge and skills in other engineering courses where relevant.
- Run focus groups with selected current engineering students and recent engineering graduates from RMIT to discuss their ideas on how teaching and learning of sustainable engineering might best be incorporated in future engineering degree programs at RMIT.

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