Future directions in the environmental education of engineers in Australia

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FUTURE DIRECTIONS IN THE ENVIRONMENTAL EDUCATION OF ENGINEERS IN AUSTRALIA

A thesis submitted in fulfilment of the requirements for the award of the degree of

MASTER OF EDUCATION HONOURS

from

THE UNIVERSITY OF WOLLONGONG

by

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Faculty of Education

2000
This thesis is submitted to The University of Wollongong, and has not been submitted for a higher degree to any other University or Institution.

Fady G. Sidrak

March, 2000
May he kiss me with the kisses of his mouth!
For your love is better than wine.

Song 1:2
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To all the environmental researchers whose writings have inspired me throughout the study, most especially Gary Codner, Duyen Nguyen and Sharon Beder.

I would like to dedicate this study to my children who have been my inspiration to struggle for an other future for all children.
ABSTRACT

The development of environmental engineering education in Australia has been marked more by indifference than enthusiasm. During the past ten years there has been a steadily growing acceptance of environmental education in every educational sphere, both in Australia and overseas.

Already there have been numerous and varied initiatives such as, new courses, new emphases placed in traditional courses, new organisations formed, new books, and journals. For the most part these have occurred in relative isolation and the result has been an increased awareness of environmental problems. But this has not necessarily been a balanced one, that leads to greater commitment to the long-term management of natural and man-made resources.

Also it has not always been based on understanding or rational argument. In part this result is due to a lack of understanding about the nature and basic objectives of environmental engineering education, and in part to the lack of coordination between different levels of educational planning. Both of these problems must be overcome if there is to be any substantial improvement in the ultimate impact of environmental engineering education.

The environmental education of engineers is an important feature of environmentally sustainable development. The study assessed the level and kind of environmental education engineers are being offered in Australia, and identified the key issues and problems facing staff who teach these courses.

This study investigated the role environmental engineering education can play in promoting ecologically sustainable development, and how such programs of environmental engineering education can best be planned and implemented.

The survey results findings are consistent with other studies and reports carried out in this field. Issues that demand to be addressed in the following findings are suggested by the academics for the future design of engineering education curricula. The key issues identified include:

It is recommended that a single corporate 'think tank' that combine the talents, experience and foresight of all the parties to give overall vision, planning and direction to the processes of modern engineering education and professional
development, community, government, industry, professional institutions and educators.

The engineering professional development and training process of engineers needs to be thoroughly reviewed with industry and graduated students to develop the formation of skills and attributes pertinent to a dynamic engineering market place. This means nothing less than a substantial investment in sustainable education modes of teaching and curricula in engineering.

Educators and trainers in engineering education and professional development must be re-equipped to deliver quality assured training and engineering sustainable education.
Personal Reflections

There are readings of the same text that are dutiful, readings that map and dissect, readings that hear a rustling of unheard sounds, that count little grey pronouns for pleasure or instruction and for a time do not hear golden or apples. There are personal readings, that snatch for personal meanings...There are believe-it impersonal readings-where the mind's eye sees the line move onwards and the mind's ear hears them sing and sing. Now and then there are readings which make the hairs on the neck...stand on end and tremble, when every word burns and shines hard and clear and infinite and exact, like stones of fire, like points of a star in the dark readings when the knowledge that we shall know the writing differently or better or satisfactorily, runs ahead of any capacity to say what we know, or how. In these readings, a sense that the text has appeared to be wholly new, never before seen, is followed, almost immediately, by the sense that it was always there, that we the readers, knew it was always there, and have always known it was as it was, though we have now for the first time recognised, become fully cognisant of, our knowledge. (Byatt, A. S. 1990:471-472)

The positioning of the author has long been much problematised by poststructuralist debates on the authority of meaning, specifically on the role of the author. I believe that it is significant to relate my story here, as I see it has happened from 1996 perspective but looking back as far as 1976, because it shows how the subject positions I have occupied have altered over time. Nearly two decades ago I thought of myself as part of a movement that then seemed capable of changing the world. I thought of environmental engineering education as providing a radically new, potentially revolutionary wedge for rethinking, and accordingly, for reshaping the social, political, and economic world in which we lived. This study is a chronicle of the continuing journey of this movement.

In many ways this study documents part of a personal journey, which commenced in 1986 when I started working on Curriculum Development Committees of the Institution of Environmental Studies. My approach to environmental engineering education at the beginning of my involvement was framed both by my educational experiences as a Natural Resources Diploma and a Master of Environmental Engineering holder and by my appointment as a Senior Mechanical Engineer. Although I had joined the CDC to be part of the dissemination phase of the Egyptian Engineering Education Project, it was a fortunate coincidence of location and time in that environmental engineering education was one of the five areas initially targeted for the CDC by the Egyptian Government in 1986. It was also an interesting time to be working with such an agency which had social
reconstruction highly placed on its agenda through the leadership of its Director who was actively writing on the topic at the time, and the general climate of innovation and change which was then pervasive. For example, at the Guidelines for Curriculum Development in Egypt workshop held in 1986, the Director stated that

In view of the nature of the changes taking place, education can no longer hope to service the individual and society by extending and refining familiar ideas, curricula, and organisational patterns... Hence education must derive its criteria for action from the individuals in the societies, which it now serves and will serve.

Because of my background in engineering education I was asked to conduct a survey of the needs for environmental engineering education in Egypt for the CDC Environmental Engineering Education Committee 1986 of which I was appointed secretary, with in many instances, a service secretarial role being expected and supplied, I was the youngest person on the Committee. As a result of the work of this Committee and the subsequent Study Group on Environmental Engineering Education, which I convened, I was charged with developing and coordinating the CDC environmental engineering education program. My involvement with environmental engineering education is continuous from this time, although over the years my role and subject position has changed. In addition to being an engineer; I have been a curriculum developer, and historian of the field and leader of a community group.

My personal philosophy with respect to environmental education has also changed over this period. Initially steeped in behaviourism through engineering education in my undergraduate studies and with the Egyptian Engineering Education Project, I gradually came to argue that the aims of environmental engineering education

Cannot be achieved through any one subject or discipline area. Rather, their achievement will involve all students and all subject areas at all levels. **Environmental engineering education is an orientation in the curriculum** or “the impregnation of our education by the subject matter, principle, methods and spirit of environmental engineering education”.

These aims are actually the slightly modified goals for environmental education from the Belgrade Charter (1975) and the Tbilisi Declaration (UNESCO 1978). However, I argued later: “There is little understanding of what ‘an orientation in the curriculum’ meant - it does not have a slot in the timetable therefore it does not fit anywhere-and interdisciplinary materials have not found a place in most engineering schools’ curricula”.

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With the encouragement of my Director, I adopted a Marxist framework informed by his writings and argued that environmental engineering education had been subjected to incorporation into the existing hegemony of the traditional educational paradigm in a neutralised form: the name, and the ‘acceptable’ knowledge and skills components, have been retained, while the radical action components have been deleted or diluted. This framework still informs my thinking, although the base has been expanded and modified over the intervening period.

Following this I was seduced by the dominant instrumentalist discourse and accepted the role of engineering education as a tool for achieving environmental goals, and I described the National Conservation Strategy for Egypt as being “a new beginning for environmental engineering education”. However, the notions of a socially critical curriculum also stimulated me as they related to the conceptions of environmental engineering education. In a discussion paper written around this time, I described environmental engineering education as being

> Concerned with developing a curriculum, which encourage the practice of just, participatory and collaborative decision-making and involves critical analysis of the development of the nature, forms, and formative processes of society generally and of the power relationships within a particular society. Environmental engineering education is about revealing how the world works and how it might be changed.

I then endorsed the view that environmental engineering education “is about critically examining the economic and political processes shaping the social use of nature within different, but inter-related societies and helping students recognize the struggles of those working for greater democracy and an improved environment”. I have continued to argue the relevance of critical theory to environmental education.

As a PhD holder in environmental engineering within the context of the University of Wollongong, the environmental engineering education research group provided an opportunity for me to pursue my research interests, as reflected in this study. Thus the project I started was not where I ended, but I have learned much about identity, subjectivity and myself along the way.

In doing so, and in the spirit of the quotation from Byatt (1990) with which I opened this **Personal Reflections**, I provide another reading of the same text of environmental engineering education, but one which, I hope, is toward being “wholly new” but also recognised as always having been there.
Program: A program is a plan which has been developed for a particular purpose, a plan or policy to be followed. "as in" the last program in our series on engineering education.

Course: A course is a series of lessons or lectures on a particular program. It usually includes reading and written work that a student has to do. "as in" that someone takes a course in a program.

Subject: The subject of something such as a book or talk is the thing that is discussed in it. A branch of knowledge organised into a course so as to form a suitable subject of study.

Unit: A quantity of educational instruction determined usually by a number of hours of classroom or laboratory work and by the passing of an examination. He has three units towards his degree.
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Chapter One

Introduction

1.1 Introduction

The development of environmental engineering education in Australia has to date been marked more by indifference than enthusiasm. However over the past ten years there has been a growing acceptance in every educational sphere, both in Australia and overseas, of the need for better curriculum provision. There have been numerous and varied initiatives with new courses developed, new emphases placed on traditional courses, new organisations formed, new books, journals and other resources developed.

For the most part these have occurred in relative isolation and the result has been an increased awareness, but not a comprehensive one, a new perspective on environmental problems, but not necessarily a balanced one. These have developed a greater commitment to the long-term management of natural and man-made resources, but this has not always been based on understanding or rational argument. In part this result is due to a lack of understanding or at least a lack of agreement about the nature and basic objectives of environmental engineering education, and in part to the lack of coordination between different areas and levels of educational planning. Both of these problems can, and must, be overcome if there is to be any substantial improvement in the range of provision and ultimate impact of environmental engineering education.

This study seeks to investigate the development of appropriate curriculum to overcome this problem of lack of awareness and training for engineering graduates. This study seeks to investigate the role environmental engineering education can play in promoting ecologically sustainable development, and how such programs of environmental engineering education can best be planned and implemented.

1.1.1 Background and context of the inquiry

1.1.1.1 Environmental Education for Engineers

Many works undertaken by engineers result in profound changes to the environment, both biophysical and socioeconomic. As engineers play a significant role in the planning and implementation of virtually all physical development projects, it is essential that they
approach these tasks with some knowledge of the potential environmental effects which might result from such works.

During the 1980's Australian engineering undergraduate courses have been described as being devoid of any real environmental content (Bandler, 1989). It is suggested that this is an important omission, for engineers have an obligation to consider the environmental impact of their works. A survey of engineering education programs in Australia was undertaken in 1987 by the Engineering Panel of the Sydney Division of the Australian Institution of Engineers. It indicated that whilst environmental matters were receiving more attention in contemporary courses, there was a lack of coherent focus in relating these matters to mainstream engineering concerns. Some institutions offered environmental course elements at undergraduate level, whilst others restricted them to postgraduate studies. The courses were usually optional, and it appears that a significant number of students in Australia could complete studies with no formal consideration of environmental issues or subjects in these program.

1.1.2 The Significance of the Study

This study seeks to investigate the role environmental engineering education can play in promoting ecologically sustainable development, and how such programs of environmental engineering education can best be planned and implemented.

The major objectives of the study are:

• To describe the major trends in environmental engineering education in Australia and to suggest directions for future development;

• To describe the basic characteristics of environmental engineering education as perceived by staff at various levels and in different subject areas in engineering faculties;

• To examine the nature and extent of environmental emphasis on environmental studies and in engineering education at the tertiary level;

• To identify some of the fundamental concepts associated with the present environmental movement;
There is no unique method for achieving curriculum development, implementation, and evaluation and hence no single or best curriculum plan for developing environmental engineering education. The diversity of content and teaching approaches that already exist will remain, perhaps even increase, since it reflects an almost infinite range of relevant concepts and issues. But if the same basic attitudes are to be developed in a rational and comprehensive sense there must be some form of curriculum plan or framework that extends across all levels of intellectual development. At present there seems little coherence in environmental engineering curriculum development in Australia. This is the major challenge for environmental engineering education.

In this respect the need is first to clearly establish a well defined strategy for curriculum development, implementation, and evaluation of environmental engineering education. Second to ensure that this is recognised and implemented at the state, regional and institutional levels.

1.1.2.1 The Need for Environmental perspective

Clause 1 of the Code of Ethics of the Institution of Engineers of Australia (1994), states that: “The responsibility of Engineers for the welfare, health and safety of the community shall at all times come before their responsibility to the Profession, to sectional or private interests, or to other Engineers.” p. 3.

In fulfilling such an obligation, engineers have a duty to consider the effects of their works on the total environment of the community. Environment in this sense should be understood as including all aspects of the surroundings of man kind, whether affecting him as an individual or in his social groupings.

Engineers are traditionally taught to solve specific problems such as the size of beams for a structure, the capacity of a road to cope with traffic, or the size of a motor to pump water at any given rate. The underlying approach to engineering problems tends to be to seek economical solutions to overcome technical problems. Where there are no analytical formulae based on accurate theories, engineering students are encouraged to make simplifying assumptions. They also tend to design or plan their schemes to have simple geometric forms, so that they become easier to set out and/or calculate. When confronted with an environmental problem which threatens to hinder or complicate the execution of their plans, they may either fail to perceive its existence, or resent it as an impediment to progress.
On a more general level, traditional engineering courses are believed to be deficient in preparing the profession to become involved in questions of community costs and benefits. Ironically, engineers have the earliest awareness of many proposals. Their decisions are usually regarded as first order requirements of a project. If these requirements are applied in an inflexible way, they can constrain all subsequent decisions. Engineers have an opportunity, and a responsibility, to play a leading role in encouraging public discussion and professional assessment of likely project impacts. Engineering education must equip engineers to satisfy this societal need.

1.1.3 Statement of the Problem

Reviews of environmental engineering education sources have indicated that whilst environmental matters are receiving more attention in contemporary courses, there is still a lack of coherent focus in relating these matters to mainstream engineering concerns. Some institutions offer environmental course elements at undergraduate level, whilst others have components in postgraduate studies. The courses are usually optional, and it appears that a significant number of students in Australia could currently complete their engineering studies with no formal study with an environmental perspective.

For those who remember teaching in the 1970s this may all sound like the predicament they were in then with Aboriginal Studies and Women’s Studies. It has taken until the 1990s for the curriculum, text books, and individual faculties to catch up and begin to represent issues of race and gender in a wide range of liberal arts courses, although still not without controversy. Many writers believe we cannot wait 20 years to make it essential for all students in engineering to confront the challenges of an environmentally sustainable future. Their lives and the life of our planet are already deeply affected by environmental change.

1.2 Research Questions

The world is now in a period of rapid change. Environmental issues are firmly on the engineering education agenda in a number of engineering faculties around Australia. A number of institutions have introduced environmental engineering degree programs as well as considering inclusion of environmental issues within the traditional branches of engineering education.

One prominent trend in the Australian content in the last few years has been the development of environmental engineering specialisation programs, generally emanating
from civil or chemical engineering departments. These new degree programs are aimed at producing specialist engineers to fill environmental management positions in government and the private sector.

The major research questions to be investigated will be:

i. What are the key environmental issues in contemporary engineering education?
ii. Which environmental issues should be included in an engineering degree?
iii. How should an engineering degree present such issues?
iv. Where can these issues best be incorporated into the curriculum?
v. To what extent have engineering curricula clearly modified to meet the needs of sustainable environmental management?
vi. Has such modification been sufficient and appropriate?
vii. How might these changes be implemented?
viii. Do current engineering degrees provide appropriate environmental education experience for future engineers?

In assessing whether engineering education is providing the appropriate skills and knowledge for these tasks and roles. The literature suggests that it is useful to consider these in two broad criteria.

1. An awareness of the environmental implications of their professional activities.

2. An understanding of

   - the social construction of environmental issues and of the knowledge which informs decision making on these issues;

   - the many individual paradigms which frame environmental concern within the community.

An examination of the subjects offered in engineering courses suggested that most engineering schools have responded to the first by adding a subject to the curriculum which examines environmental impact of engineering activities through case study examples, but that most engineering schools have paid little or no attention to the second in their curriculum development.
From the Engineering Code of Ethics (1994, p. 3)

‘Professional practice...in ways that recognize the community interest. This includes attention to the ecological and physical environment, the prudent use of natural and human resources and the social, economic and financial impacts of their work’.

‘The responsibility for the welfare. Health and safety of the community shall at all times come before their responsibility to sectional or private interests, or to other members’.

From the Environmental Principles (1992, p.1)

‘Engineers need to develop and promote a sustainability ethic. Engineers should practice engineering in accord with a sustainability ethic that leads to sustainable development’.

‘Recognise the rights of the community to be involved in project formulation and development and actively encourage such involvement’.

‘Learn the skills necessary to develop active community participation in engineering activities’.

‘Disclose environmental implications and external costs of engineering activities, taking into account the often inadequate and uncertain nature of environmental data’.

Environmental Principles (1992, p.1)

In sum, the complex, varied and equally legitimate views on what constitutes the ‘community interest’ must be acknowledged and understood. Few engineering courses in Australia were identified as adequately meeting this need.

What curriculum changes are required to provide appropriate environmental education for future engineers?

‘One of the most difficult concepts to get across is that there is no such thing as an objective, external “real” system, but that all systems are constructs of the mind’

(Elms, 1989, p. 3.)
If as argued above, the social context and community input are to be regarded as centrally important aspects of engineering practice, the skills and knowledge necessary for engineers to deal with these issues must be fully integrated into the engineering curriculum such that they appear as an integral part of engineering practice of equal importance to, and inseparable from, the technical aspects.

1.2.1 Nature of the Programs

Although it should be a long term aim to integrate environmental considerations into engineering programs, this may not happen in the short to medium term. The depth of environmental concerns in an engineering course currently vary with the lecturer, so that while some programs will have a good coverage of relevant environmental issues, others will, at best, present only a narrow perspective of such problems e.g. the technical solutions, but not the social and economic ones. It is argued in the thesis that in the short term a specific environmental subject within a program may be the only immediate way to achieve practical environmental goals, but it will not provide the intended results for environmental responsibility and sustainability.

The question has also been raised whether such training should be at undergraduate or postgraduate level. It seems logical that environmental training would be best undertaken at the undergraduate level since it is the only forum which will reach all beginning engineers. Furthermore, the environmental component of engineering should be an integral part of engineering practice. Hence environmental training at the earliest practicable stage should help promote the automatic inclusion of environmental factors at the initial stages of planning for engineering works.

1.2.2 Program Objectives

It is suggested that a suitable environmental engineering program should satisfy the following objectives (Bandler, 1989, p. 3) and their rationale:

- **To foster a view that environmental sensitivity is an integral part of all good engineering.** Environmental considerations are not something of peripheral concern, but are central to the competent design, construction and operation of engineering works. Environmental values should not be optional extras clipped onto a project at great cost after it is fully designed, but must be a fundamental element in project evolution. The objective implies a requirement for knowledge of environmental issues and legislation. It is essential that undergraduate engineers be made aware of potential environmental implications of engineering works. There is a need to engender
environmental sensitivity at an early stage in the education process. Good engineering is inseparable from an awareness of sound environmental principles.

- **To achieve a basic understanding of environmental principles.** This objective implies an appreciation of the differences between renewable and nonrenewable resources. Engineering undergraduates should be made aware of interrelationships between different components of the natural and man-made environment. It is probably best achieved by a systems approach to environmental education.

- **To broaden the horizons of engineering undergraduates.** It would be desirable to expose engineering students to professional disciplines in the social and natural sciences that they would not encounter elsewhere in their courses. Although this contact would necessarily be relatively superficial, it must be made meaningful. It would also be of benefit to allow students to interact with contemporaries from other faculties having different professional backgrounds, training and values.

- **To enhance the group interaction and communication skills of engineering undergraduates.** Engineers often have a problem communicating with professionals from the natural and social sciences. This can lead to misunderstanding and conflict when many words are spoken but no transfer of information takes place. A core environmental course could give a unique opportunity to bring together undergraduates from a variety of faculties for group projects. Such a course segment would provide students with a realistic example of the achievement of group results from a number of individuals whom they did not pick, with expertise with which they were unfamiliar in an overall timetable which they did not set. This will forcibly bring forward the value of group dynamics, communication skills, project organisation and the need to appreciate the perspective of others.

- **To provide an appreciation of the importance of values in engineering decision making.** Some engineers tend to approach their professional task with little appreciation of the importance of non-technical factors. Attitudes to man nature relations, for example, are dynamic and affected by a host of cultural and social determinants. Engineering works are carried out in a context of political and economic relationships whose relevance should be recognised.

1.3 **Research Design**

The research design was a descriptive summary of 18 Australian undergraduate engineering programs, evaluation made use of, questionnaire, interviews and document
samples. The research instruments were developed and trialed within the University of Wollongong, and the four environmental groups listed below provided input and comment.

1. Environmental Engineering
2. Environmental Science
3. Science and Technology Studies
4. Environmental Education

1.3.1 Mode of Inquiry

The research used a mixed mode of quantitative and qualitative data gathering approaches. The questionnaires were conducted firstly within University of Wollongong environmental groups to arrive at a series of modified questions for the survey.

1. A review of educational policies at both state and institutional levels, and of educational programs and specific courses of study was conducted. This information was largely derived from government gazettes and information bulletins, institutional handbooks and prescribed syllabus outlines.

2. A systematic content analysis of relevant curriculum resource materials in science, social studies and geography.

3. Postal questionnaires to various tertiary staff dealing with content, objectives, reference materials, teaching approach and assessment procedures of courses broadly related to environmental engineering education.

4. Personal interviews with teaching and administrative staff at tertiary institutions concerning general policy on staffing and curriculum organisation, and details of relevant educational programs.

1.3.2 Instruments

Since this was a mixed mode study, data analysis achieved by using the appropriate statistical tests for the quantitative data. Groups of staff were selected and interviewed to follow up the information gained from the questionnaire. Data from these interviews were analysed for themes and trends that related to data from other resources.
1.4 Ethical Considerations

Since the need for follow up through subsequent responses makes anonymity impossible, each respondent was allocated a code number for the recording of responses and to maintain the record of the associated names separately and only for the purpose of the follow up surveys and interviews.

A letter detailing the nature and purpose of the research, the steps taken to ensure confidentiality send to all participants at the time of requesting access or participation. Ethical Committee approval was obtained before any data were collected.

1.5 Summary of thesis

Figure 1.1. provides a brief background and outlines the context of the inquiry also the aims and objectives of the research are identified.

![Flowchart of this thesis](image)

**Figure 1.1 Flowchart of this thesis**
A review of the literature about sustainable engineering education is reported in Chapter 2. The concept of sustainable engineering education has been developed in this overview. A bit more Chapter 3 reviews the diversity of approaches to environmental education in Australian Universities. This review covers both basic academic studies and professional training.

Chapter 4 develops the degree with full details of the documents, procedures and methods used for sampling and analysis of the survey data.

In Chapter 5 the data analysis of the survey is presented. The data focuses on environmental sustainable development, the environmental education of engineers, barriers to the development of environmental education of engineers, and possible syllabus change. The conclusions of the study are presented in Chapter 6 along with recommendations for further research.
Chapter Two

Literature Review

Sustainable Engineering Education

2.1 Introduction

Perhaps the 1992 Earth Summit marks a twenty year cycle, and we have 'arrived where we started'. We know this place, and these crises are familiar, but the feeling is not one of deja vu. Things have changed, and these changes call for redoubled learning and exploration of new ethical, political, economic and educational paradigms. We know much better the territory and solutions that have to be explored. But time is short and, it must be said, the caliber and extent of current debate on the interface between environmental survival and the role of education is disappointing. Whether education as a whole can be bold enough to develop an adequate response, on a scale commensurate with the issues that have to be addressed over the next decade, remains a crucial question (Sterling, 1992, pp. 1-2).

Stephen Sterling wrote these words in an editorial to the 1991-92 edition of the Annual Review of Environmental Education. He reminded his audience of the 1972 Stockholm Conference and that environmental education is once again being promoted as a vehicle for social change through more sustainable forms of development. He suggests that environmental educators have made limited progress during the past twenty years, and advocates more debate on the interface between education and environmental problems informed by holistic, ethical, political, economic and educational paradigms.

The purpose of this chapter is to analyse the current state of the integration of environmental sustainable education into engineering courses and education institutions throughout Australia. The chapter considers how institutions have adapted their engineering courses in response to the demand for environmentally sustainable development, as well as changes within the engineering discipline and profession. The chapter examines both the education of environmental engineers and the education of traditional or conventional engineers to understand how and if these disciplines are adapting.
2.2 Education for a sustainable future

The year 1990 marks the beginning of a decade of significant importance for environmentalists and environmental educators (UNESCO-UNEP, 1989, p.1).

The last decade has witnessed heightened public awareness of the scale, severity and complexity of many environmental problems. Numerous reports indicate that public concern for the environment is at unprecedented levels in Australia and, indeed, throughout the world (Dunlap, Gallup & Gallup 1992; ANOP Research Services 1992). Concern has been growing since the early 1960s over problems as diverse, yet global in impact, as atmospheric warming and climatic change, the destruction of rainforests and threats to biodiversity, accelerating rates of land degradation and desertification, population-resource imbalances, urban decay, nuclear accidents, the disposal of toxic wastes, and a range of other threats to the quality of human life and the sustainability of ecosystems. Acknowledging this concern, "Time" magazine chose to honour 'Endangered Earth' instead of a Man or Woman of the Year in 1988. The lead story writer explained that:

... worldwide public opinion ... sensed that this gyrating globe, this precious repository of all the life that we know of, was in danger. No single individual, no event, no movement captured the imagination or dominated headlines more than the clump of rock and soil and water and air that is our home. Thus, in a rare but not unprecedented departure from its naming a Man (sic) of the Year, "Time" has designated Endangered Earth as the Planet of the Year for 1988 (Sanction, 1989, pp. 11-12).

People in the 1990s are becoming increasingly aware that humankind is an important part of the environment. Instead of seeing the environment as just nature and natural systems, the environment is being recognised as the totality of our surroundings and existence which results from the way we use nature and its resources to satisfy our needs and wants. This means that the environment is interpreted as a complex web of social, cultural, economic and political as well as geo-and biophysical components. There is a growing realisation that environmental problems cannot be understood without reference to social, economic and political values, and that managing the environmental crisis will depend upon changes in environmental values and lifestyle choices. Thus, Schleicher (1989, pp. 277-278) writes of the need for a new 'ecological ethic, ... an ecologically
oriented value system’ based upon ‘fundamental changes in human attitudes and actions towards ourselves and the environment’.

The scope of such a change in social values has been likened to a change in social paradigms or world views. This would involve a process of change towards social systems, institutions and practices guided by values such as: empathy with other species, other people and future generations, respect for natural and social limits to growth, support for careful planning in order to minimise threats to nature and the quality of life, and a desire for change in the way most societies conduct their economic and political affairs (Milbrath, 1989, pp. 58-870).

While there is debate about particular directions and the pace of this ‘paradigm shift’ and about the effectiveness of different strategies for social change, there seems to be wide agreement, both in Australia and internationally, that education has an important role to play in motivating and empowering people to participate in environmental improvement and protection. Indeed, as early as two decades ago, education was described by one commentator as ‘the greatest resource’ in this endeavour (Schumacher, 1973, p. 64).

The National Conservation Strategy for Australia (NCSA, 1984) identified environmental education as a major priority for redressing the environmental problems facing Australia. In 1989 the Australian government launched a national environmental education strategy under the theme of ‘Learning for our Environment’ (Dawkins, 1989). The strategy stressed the need for ‘children to become actively involved in environmental issues at a practical level’ (p. 1) because:

When one considers that the next few decades or so are going to be crucial to the future of our planet, the way in which our children are prepared to deal with environmental issues will be very important to our success in solving environmental problems (p. 2).

The importance of environmental education was stressed in the four major international environmental reports of the last decade also. The theme of these reports is the search for sustainable patterns of development and living that can redress present day environmental decline without jeopardising the ecosystem or resource base for future generations.

The Brundtland Report of the World Commission on Environmental and Development (1987) argued that ‘the world’s teachers… have a crucial role to play’ in helping to bring about ‘the extensive social changes’ needed for sustainable development (p. xiv). The
1980 World Conservation Strategy was quite explicit about the role of education in bringing about such changes. It argued that:

Ultimately, the behaviour of entire societies towards the biosphere must be transformed if the achievement of conservation objectives is to be assured. A new ethic, embracing plants and animals as well as people is required for human societies to live in harmony with the natural world on which they depend for survival and well-being. The long term task of environmental education is to foster or reinforce attitudes and behaviours compatible with this new ethic (IUCN, UNEP and WWF, 1980, Section 13).

This message was repeated in Caring for the Earth: A Strategy for Sustainable Living which was prepared as the World Conservation Strategy for the 1990s (IUCN, UNEP and WWF, 1991). Caring for the Earth argues that education has a vital role to play in ensuring that people learn, accept and live by the principle that 'living sustainably depends on accepting a duty to seek harmony with other people and with nature' (p. 8):

Sustainable living must be the new pattern for all levels: individuals, communities, nations and the world. To adopt the new pattern will require a significant change in the attitudes and practices of many people. We will need to ensure that education programs reflect the importance of an ethic for living sustainably (IUCN, UNEP and WWF, 1991, p. 5).

Agenda 21 is the internationally agreed report of the United Nations Conference on Environmental and Development or ‘Earth Summit’ which was held in Rio de Janeiro in June 1992. Agenda 21 devotes a whole chapter to the role of environmental education in relation to sustainability:

Education is critical for promoting sustainable development and improving the capacity of the people to address environmental and development issues... It is critical for achieving environmental and ethical awareness, values and attitudes, skills and behaviour consistent with sustainable development and for effective public participation in decision-making (UNCED 1992, Chapter 36, p. 2).

The theme of ecologically sustainable development which is central to all these reports calls for environmental education to be central to the vision of a desirable society. For example, the study, Visions of a Future Australian Society: Towards an Education Curriculum for 2000 AD and Beyond, by Campbell, McMeniman and Baikaloff (1992) for the Queensland Ministerial Consultative Council on Curriculum found that ecological
sustainability ranked second only to social justice in a ranking of 22 societal and educational goals. It is important to understand what is meant by ecological sustainability in such an expectation of education. Unfortunately, definitions of sustainability do vary (Fien, 1993a; Orr, 1992). However, at the heart of sustainable development is the mitigation of the impacts humans make on the earth and the way we organise the flows, production and distribution of resources and wastes, which in turn affect what political scientists define as the essential questions of public policy: ‘Who gets what, when, and how?’ (after Orr, 1992, p. 145).

When sustainability is bracketed with social justice in visions of desirable futures, it is possible to identify a definition of sustainability and a range of related issues that education should address if those visions are to be achieved. Such a definition of sustainable development sees it as a process which requires that the use of environments and resources by one group of people does not jeopardise the environments and well-being of people in other parts of the world or destroy the capacities of future generations to satisfy their reasonable needs and wants. In their teaching pack, *Only One Earth*, Beddis and Johnson (1988) argue that a number of issues and questions linking ecological sustainability and justice flow from such a view. These include:

- There are great differences in the availability and use of resources around the world with great poverty and need in some areas and wasteful overproduction and over-consumption in others.

  *How can the over-consumption, waste and misuse of resources by some people be reduced? How can the severe poverty that causes many to exploit the earth just to survive be eliminated and such pressure on the environment removed?*

- Some economic activities do great harm to environments, resources and communities.

  *How can economic activity be made of benefit to both the companies and the communities affected, and without critical damage to the environment?*

- The population in certain parts of the world is increasing at an alarming rate adding to the pressure on environments and resources.

  *How can population growth be restrained to match the availability and sustainable use of resources?*
Economic growth in some parts of the world is so high that it is leading to the production and consumption of many items that are super-luxuries and use resources that could be used to satisfy the needs of many of the world's poor.

*How can the resources consumed by such luxuries be redirected to aid the poor or be conserved for future generations?*

The most effective arena for action on sustainability and justice issues is the local community.

*How can people best organise themselves locally—and liaise with others nationally and globally—to collaborate in the crucial aims of sustainable development?*

These are issues that environmental educationalists have been slow to address. In concentrating on issues of class and economic reproduction and the reproduction of racial and gender inequalities educationalists have been slow to analyse the relationship between education and the processes of the world economy, the nature of the dominant model of what counts as economic development, and the environmental destruction upon which it is based. D'Urso (1990) has described the environmental crisis and educational responses to it as ‘curiously neglected by socio-cultural theorists of education’ and urges them to strike ‘beyond the bounds of current educational concerns’ to establish environmental education as ‘a new and vitally important discourse’ (p. 92).

Only recently has this analysis been extended to consider the relationship between education and the reproduction of the environmental values and practices of global capital. For example, Trainer (1990) has argued that both the overt and the hidden curricula of schools play a major role in reproducing the ecologically unsustainable values of ‘industrial, affluent, consumer society’ (p. 105), including the desirability of economic growth and a competitive economy, the importance of self-advancement, and the correctness of allowing the profit motive and the market to determine economic and social priorities (p. 107). In addition, Berberet (1989) has noted that, while the environment has been only ‘a minimal factor in mainstream educational thinking’ (p. 3), education has played a key role in perpetuating unsustainable environmental practices:

*Historically, the values of schools and colleges have mirrored those of the larger society. Not only has education uncritically accepted the association of progress and the unfettered growth economy, it has trained the engineers and managers, performed the research, and developed the technologies which in aggregate have*
had such a devastating impact on the environment. A fundamental reorientation now needs to occur with the development of new assumptions undergirding education which treat the interactions of ecological processes, market forces, cultural values, equitable decision-making, government actions, and environmental impacts of human activities in a holistic, interdependent manner (pp. 4-5).

These are serious claims which need to be considered and tested and, if they are found to be valid, warrant urgent attention at all levels of education, including teacher education. Issues of environment, social justice and sustainable development do pose important questions for the future of human society. They are also important for those who wish to teach for a just and sustainable future and those who are involved in the education of such teachers. This means that those involved in environmental education, at whatever level, need to recognise its socially critical or reconstructionist orientation and promote approaches to curriculum planning and pedagogy that can help integrate social justice and ecological sustainability into a vision and a mission of personal and social change.

However, not all approaches to environmental education emphasise these issues and the social changes needed for sustainable living. Indeed, there is sometimes contestation over the relative importance of different knowledge, skill and affective objectives and the social and political interests served by different approaches to environmental education (Robottom, 1987a). Nevertheless, there is growing consensus in United Nations reports on environmental education, the environmental education literature, and the policies and curriculum guidelines developed by education systems throughout Australia that environmental education needs to address a wide range of knowledge, skill, values and participation objectives. In order to help students play an informed and active part, both now and later as adults, in the resolution of environmental questions, issues and problems and the creation of a fairer, less troubled, and more sustainable world in which to live.

2.3 What is environmental education?

The nature and goals of environmental education have been formulated through a number of international, national and state initiatives over the last two decades. The International Environmental Education Program which is jointly sponsored by UNESCO and UNEP (United Nations Environment Program) has taken the lead in these initiatives. Thus, among the most authoritative statements on environmental education are those recommended and endorsed at the 1977 Intergovernmental Conference on Environmental
Education held in Tbilisi (UNESCO-UNEP, 1978) and subsequently re-endorsed at the International Congress on Environmental Education and Training in Moscow in 1987 (UNESCO-UNEP, 1988). These statements have been used as the basis for policy development in environmental education by the Commonwealth and all States and Territory governments in Australia (Greennall, 1987; Greenall Gough, 1990).

The Tbilisi Declaration provides a general set of goals, objectives and principles for environmental education. The goals agreed for environmental education are:

1. To foster clear awareness of, and concern about, economic, social, political and economic interdependence in urban and rural areas;
2. To provide every person with opportunities to acquire the knowledge, values, attitudes, commitment and skills needed to protect and improve the environment; (and)
3. To create new patterns of behaviour of individuals, groups and society as a whole towards the environment (after UNESCO-UNEP, 1978, P. 3).

The five categories of objectives agreed for environmental education are:

1. Awareness: to help students acquire an awareness of, and sensitivity to, the total environment and its allied problems.
2. Knowledge: to help students gain a variety of experiences within the total environment and develop a basic understanding of the total environment, its associated problems, and humanity’s critically responsible presence and role in it.
3. Attitudes: to help students develop a set of values and feelings of concern for the environment and the motivation to participate actively in environmental improvement and protection.
4. Skills: to help students acquire the skills for identifying, investigating and solving environmental problems.
5. Participation: to provide students with the understandings, skills and self-esteem, as well as opportunities to be actively involved at all levels in working toward the resolution of environmental problems (after UNESCO-UNEP, 1978, p. 3).

The guiding principles agreed for programs in environmental education based upon these goals and objectives emphasise that environmental education should:

- consider the environment in its totality—natural and built, technological and social (economic, political, cultural-historical, moral, aesthetic);
- be a continuous lifelong process, beginning at the pre-school level and continuing through all formal and non-formal stages;
• be interdisciplinary in its approach, drawing on the specific content of each discipline in making possible a holistic and balanced perspective;
• examine major environmental issues from local, national, regional and international points of view so that students receive insights into environmental conditions in different geographical conditions;
• focus on current and potential environmental situations while taking into account the historical perspective;
• promote the values and necessity of local, national and international cooperation in the prevention and solution of environmental problems;
• explicitly consider environmental aspects in plans for development and growth;
• enable learners to have a role in planning their learning experiences and provide an opportunity for making decisions and accepting their consequences;
• relate environmental sensitivity, knowledge, problem-solving skills and values clarification to every age but with special emphasis on environmental sensitivity to the learner’s own community in early years;
• help learners discover the symptoms and real causes of environmental problems;
• emphasise the complexity of environmental problems and thus the need to develop critical thinking and problem-solving skills;
• utilise diverse learning environments and a broad array of educational approaches to teaching/learning about and from the environment with due stress on practical activities and first-hand experience (UNESCO-UNEP, 1978, p. 3).

A number of brief definitions of environmental education have been developed to reflect the goals, objectives and principles of the Tbilisi Declaration. In the United States of America, Hungerford, Peyton and Wilke (1980) have described environmental education as a process for aiding people to become ‘environmentally knowledgeable and, above all, skilled and dedicated citizens who are willing to work, individually and collectively, towards achieving and/or maintaining a dynamic equilibrium between quality of life and quality of the environment’ (p.43). In Australia, the Environmental Education Project conducted by the Curriculum Development Centre determined that:

Environmental education is a process which is applicable to everyone and so should be directed at people of all ages. Its purpose is to produce an environmental literate citizenry who will have the basic knowledge of and concern for the environment, awareness of the implication of issues, basic skills to cope with issues and initiate solutions, as well as motivation and commitment to the measures of environmental management (Womersley & Stokes, 1981a, p. 10; 1981b, p. 10).
The Bicentennial Australian Studies School Project defined environmental education in similar terms as:

... an across the curriculum approach to learning that is useful to individuals and groups in coming to understand the environment with the ultimate objective of developing caring and committed attitudes that will foster the desire to act responsibly in the environment. Thus, environmental education is concerned about knowledge, and also feelings, attitudes, skills and social action (Fien, 1988, p. 10).

Achieving these goals and objectives involves the integration of three approaches to environmental education—education in the environment, education about the environment and education for the environment.

2.3.1 Education in the environment

Experience in the environment, be it in a city street, a beach, a park, a farm, a forest or the school grounds, can be used to give reality, relevance and practical experience to learning. Increased awareness of aspects of the environment can be expected from any opportunities for direct contact with the environment. Opportunities to learn out of doors can also be used to develop important skills for data gathering, such as observation, sketching, photography, interviewing, and using scientific instruments, as well as social skills such as group work, co-operation and aesthetic appreciation. Environmental awareness and concern can also be fostered by linking learning to direct experiences in the environment and allowing learners to become captivated by the complexity and wonder of natural systems or immersed in the values conflict over particular environmental issues.

2.3.2 Education about the environment

Such feelings of concern are not enough, however, if living responsibly and sustainably in the environment is an educational goal. Concern needs to be translated into appropriate behaviour patterns and action but, for this to happen, it is essential for learners to understand how natural systems work and the impact of human activities upon them. This will include learning about political, philosophical, economic and socio-cultural factors as well as about the ecological ones that influence decisions about how to most responsibly use the environment. Knowledge about the environment is essential if all citizens are to participate in any informed debate aimed at resolving local, national and global environmental issues. There is much that many non-formal avenues of
environmental education, as well as formal curriculum areas, including the arts as well as the natural and social sciences, can contribute to providing such knowledge.

2.3.3 Education for the environment

Education for the environment aims to promote a willingness and ability to adopt lifestyles that are compatible with the wise use of environmental resources. In so doing, it builds on education in and about the environment to help develop an informed concern and sense of responsibility for the environment through the development of an environmental ethic and the motivation and skills necessary to participate in environmental improvement. Education for the environment may be located within the socially-critical traditions in education because of its concern for social critique and reconstruction. As the final report on the Tbilisi conference (UNESCO, 1980) stressed, environmental education must be based upon a search for answers to a number of critical questions:

As decisions regarding the development of society and the lot of individuals are based upon considerations, usually implicit, concerning what is useful, good, beautiful, and so on, the educated individual should be in a position to ask such questions as: Who took this decision? According to what criteria? With what immediate ends in mind? Have long-term consequences been calculated? In short, he (sic) must know what choices have been made and what value-system determined them (p. 27).

2.3.4 Education in, about and for the environment

Reflecting on the relative strengths and weaknesses of these three approaches to environmental education in relation to the values transformation necessary to promote sustainable and socially just lifestyle choices, has led most Australian (e.g. Fien, 1988, 1993b; Greenall Gough, 1990; Lucas, 1979; Robottom, 1984) and overseas environmental educators (e.g. Huckle, 1983) to argue that it is only when the overall intention is education for the environment that real environmental education is actually taking place. Such writers argue that education in and about the environment provide most educational value when they are used to provide skills and knowledge to support education for the environment.

The integration of these three approaches to environmental education means that it is aimed at educating citizens who are knowledgeable about the natural and social environment, skilled in researching environmental issues, aware of how to help resolve
these issues, and motivated to work towards a better environment for all. Coordinating the contribution of the many subject areas that can contribute to these objectives requires a whole school planning approach to environmental education. This can be achieved by focusing planning around a core of central concepts and pupil-centered pedagogical approaches.

2.4 Key concepts for environmental education

There have been a number of attempts to identify key concepts for environmental education (e.g. Hungerford, Peyton & Wilke, 1980; Huckle, 1988; Meadows, 1989). Four concepts that are common to these listings and which reflect the integration of education in the environment, about the environment and for the environment are: interdependence, resource management, values and lifestyle choices, and social action.

1. Interdependence: People are an inseparable part of the environment. We are part of a system that links individuals, their culture and the bio-physical world of nature.

The environment contains three elements: nature, culture and individuals. All three are linked as interdependent parts of a system from which the individual cannot be isolated. Each of us is a part of a culture and our individual perceptions and actions contribute to the total impact of humans on the bio-physical world. We are also part of a culture that has developed an economic structure, technological processes and a political system that allows individuals to obtain the goods and services necessary to maintain a particular lifestyle or way of life.

The fundamental issue in this interdependent natural and social system we call the environment is that it is individuals who have the ability to strengthen, weaken or maintain the relationships between the three elements in the system. Environmental education teaches that everyone has a responsibility to develop and maintain high quality natural and social systems in which individuals know how and are willing to act only in ways that will advance human well-being and maintain ecological sustainability.

2. Resource Management: The bio-physical world contains a range of renewable and finite resources that people can develop to satisfy their needs and wants according to the lifestyle choices they make.

The survival and well-being of any society depend upon its supply of natural resources to maintain life (air, water, etc.), to satisfy basic needs (shelter, food, etc.) and to provide a
certain degree of comfort, convenience and even luxury (cars, electrical goods, air conditioning etc.). Everyone is influenced by the values and expectations of his or her society and, as individuals, will make lifestyle choices that depend on consuming resources to a greater or lesser extent. Environmental education can help students develop a sound understanding of natural resources—their characteristics, distribution, status, and present and potential uses in order to make informed decisions on which resources to consume for which purposes. This involves learning about the natural world and the functioning of ecosystems as well as about the way different cultures have perceived and used resources. In addition, students need to appreciate that, as people use natural resources, they alter the bio-physical world and create a variety of human landscapes such as mining landscapes, farming landscapes, small country towns and large cities.

Understanding these landscapes and the resultant ways of using resources involves some familiarity with the impact of technology on society and its use of natural resources, various ideas for urban and rural design, the operation of transport systems, and the nature of the political and legal systems that control the use of resources. A fundamental environmental education value behind such understandings is a commitment to the belief that the use and management of resources should aim at high quality natural and social systems that enhance human well-being in balance with ecological sustainability.

3. **Values and lifestyle choices:** The ecological balance of natural ecosystems is always affected by the degree of human impact in the development of resources. Sometimes, the environmental problems that result from the unplanned or unwise use of resources are so severe that changes in management practices and human lifestyles are necessary to ensure ecologically sustainable development.

The indigenous people of many societies have shown that it is possible to live in a state of relative balance and harmony with the environment. These societies developed a culture that views people and the natural world as inseparable. However, these ecologically sustainable societies have been supplanted in many parts of the world by social and economic systems that largely view nature as a 'cornucopia' to supply resources to satisfy every human need and want. The consequences of this view are reflected in the wide range of environmental problems facing the world today: climatic change on a global scale, soil erosion and desertification on a continental scale, disappearing forests, many lost or endangered species of animals and birds, pesticide residues in pasture lands and rivers, the seemingly endless sprawl of suburbia, and congested, polluted city centres. These problems are caused by a complex set of social values and human expectations about 'the good life' and their resultant impacts on the limits of natural systems.
The study of such issues contributes to the objectives of environmental education by helping students to become responsible environmental citizens. This involves learning how to clarify their values in relation to environmental problems, how to identify the root causes of environmental problems, and how to work towards the solutions of these problems through proper planning, using the legal system, new laws, political participation, improved resource management practices, research and technological developments. Through learning how people in different parts of the world have practiced these skills and clarifying how they relate to local environmental situations, student can come to understand that the resolution of some of these problems will be impossible if society does not act as a whole to alter particular perceptions of the environment and adopt new, more responsible lifestyle practices.

4. **Social participation**: Attitudes of concern for the quality of the environment are important to motivate people to develop the skills necessary to find out about the environment and to be willing to take the necessary decisions and actions for environmental problem-solving.

The words ‘attitude’, ‘decisions’ and ‘actions’ in this context must be based upon more than a knowledge of environmental information. They imply a combination of informed concern and a willingness to act. Environmental education programs that only teach about the environment will be little more than ‘water off a duck’s back’ unless they provide opportunities for students to explore alternative environmental values and to develop an appreciation and concern for ecological sustainability and human well-being. Such attitudes are necessary to motivate young people both now, as students, and later, as adults, to seek solutions to environmental problems. While knowledge and skills provide an important foundation for responsible environmental behaviour, especially knowledge of how to work effectively with others to solve environmental problems, they count for nothing unless the important affective domain is activated. The World Commission on Environment and Development has argued that these environmental values objectives ‘cannot be achieved without the involvement of students in the movement for a better environment’. Thus, active involvement in environmental protection and improvement projects is an essential element of environmental education. Of course, action is always the most difficult element to achieve, but if it is not there in some way, one is left with education for its own sake, nothing more.
Curriculum planning and pedagogical issues are interdependent aspects of the process of teaching. Guiding learners towards a comprehensive understanding of the key ideas in environmental education and the associated skills, attitudes and values requires approaches to curriculum planning and pedagogical patterns markedly different from the traditional concept of the staff as the disseminator of discipline-based knowledge.

In relation to curriculum development, effective environmental education requires cooperative planning between staff and departments in a school or faculty. New forms of curriculum organisation based upon the interdisciplinary and multidisciplinary study of questions, issues and problems or relevance to students and their communities-and a gradual widening of the perception of what a “community” is so that students appreciate the global nature of contemporary life are required. Such practices replace subjects with the needs of students and their communities and professions as the centre of the curriculum planning process. This requires a reconceptualisation of curriculum so that knowledge and skills selected from the disciplines are seen as means to the ends of education rather than as ends in themselves. This view of curriculum has implications for syllabus design and the planning of work programs, assessment procedures in schools and faculties. It also has implications for the way teaching and learning are approached. Environmental education pedagogy is based upon a view of teaching as a creative and dynamic process in which students and staffs are engaged together in a search for solutions to environmental problems. This emphasises approaches to teaching which involve:

- the active investigation of real problems, rather than abstract and distant concerns, with an emphasis on problem solving and decision-making;
- lots of first-hand experiences in a range of environmental settings
- close interaction between faculties, staff, students and the community;
- the development and application of skills for scientific and social investigation—observation, measurement, classification, experimentation, prediction, analysis, interpretation, synthesis, evaluation and decision-making, etc.;
- using the values of sustainability, democracy and social justice as criteria for judging the validity of answers to questions such as: Who took this decision? According to what criteria? With what ends in mind? Have the long term consequences been calculated?;
- the development of a sense of pleasure, wonder, curiosity and excitement in learning;
- the clarification, analysis and critique of students own viewpoints and values and those of other individuals, groups and institutions.
These principles for teaching and learning in environmental education give rise to pedagogical patterns based upon a variety of individual and group learning experiences and a variety of teaching strategies, such as inquiry learning, simulation, and role play. Action research, as a powerful strategy in which the students retain the focus of control in learning and decision making. Power is shared between students and staff wherever and whenever possible. These aspects of pedagogy reflect the best of contemporary thinking and practice in education today. The next phase of the chapter examines the environmental engineering education to understand how and if sustainable engineering education disciplines are adapting.

2.6 Environmental Engineering Education

2.6.1 Introduction

The focus is on the fundamentals that is, on foundation ideas. For undergraduates, the foundations lie in the early level teaching on which environmental engineering education is based. For engineers in practice, they represent basic ideas, techniques and outlooks that complement continuing engineering education courses with a more detailed focus.

"Environmental engineering", is taken in a broader, rather than a narrower construct. As well as the more directly involved environmental engineers who deal with a variety of technical matters ranging from waste treatment and pollution control to impact assessment, it could be said that all engineers need to be well aware of environmental issues and needs. All engineers need to be environmentally literate.

Engineering education is a complex task. Curricula are intricate, and piecemeal changes of any depth are far from easy. It is argued that what is really required is to review the foundation subjects on which programs are built. It is at this fundamental level that any deep innovation, responding to a change in the world’s requirements for engineering skills, must begin.

2.6.2 Modern Problems and Changing Needs

Modern problems in environmental engineering are becoming more complex. Once factories and furnaces could operate with no thought to the consequences of pollution and the limitations on resources of material, time and space or of the people and societies with which they interacted. However this is not so today. As the cost of pollution, both past
and present, becomes more clearly defined and obvious, systems of production and reception are seen in their totality. Loops are closed, and the complexity born of feedback and of a myriad of competing interactions reveals new problems, whose nature becomes more urgent as they become more difficult.

The increase in complexity goes further than environmental engineering. It has come to pervade the whole of technology, and it reaches far beyond. Engineers are considering problems, though, need driven problems as engineers perceive them, and not the world itself. The world has always been complex, but engineers seldom see it as it really is. Engineers choose what to see, both as individuals and, through convention and fashion, as social groups. Engineers interact with the world, but only see that part of it revealed through our worldwide, our "weltanschauung".

Thus, engineers have not seen complexity because engineer's have not needed to, and engineers have not dealt with it because engineers have not had the tools with which to do so. Now, though, engineers are forced to look as they begin to sense the limits of our world system, while at the same time, through computers, engineers begin to have the tools needed to understand and handle complexity.

Engineers ability to compute, to model and deal with information by electronic means has now far 'outstripped our ability to understand what it is that engineers model. The gap, and the real need, is conceptual and philosophical. In this area, engineers hardly know where to begin. A few brave souls, though, are trying to find a path through the blank areas of our understanding.

To return to the matter of why engineering problems are increasingly complex, it is partly a matter of need, and partly one of a new paradigm, a new way of looking at the world. It is also a matter of engineering problems no longer being neatly packaged into technical issues. Much of the complexity seems to occur where traditional "technics"-that is, technical matters-impinge on and interact with wider systems. Where technics meet the natural and social environments, engineers experience the characteristic complexity typically faced by environmental engineers among others. Where they interface with ownership and capital, again the problems are complex, though the complexity is of a different kind.

It is also a matter of engineers are being required to extend the boundaries of what they do into wider problems and into societal needs beyond immediate technical matters that another change arises in the nature of engineering problems. As well as increasing in complexity, they are increasing in breadth, in scope. This has implications for both
knowledge and for the way in which engineers must work. Knowledge must be more broadly based, and there is an increasing need to work closely with a range of professionals and other stakeholders.

Finally, the new types of engineering problems are no longer crisply defined. The boundaries of the systems are not clear cut, and the value systems required are no longer easily quantified. Even where they are, engineers may well be working with many incommensurable values that cannot readily be compared with one another. The well defined and obvious boundaries of a concrete beam, a connecting rod or an electric circuit are still there. They are very much a central part of engineering. But the boundaries of the appropriate systems to be considered when dealing with the interaction between a new dam and the natural environment surrounding it are not as clear.

How far from the dam might the effects spread?
What is their dynamic nature over time?
Will major effects arise from seemingly minor changes to water temperature, food supplies, travel paths and so on?
Or, because a dam is a major hazard and a risk assessment is necessary, how much detail should the assessment include?
What are the possible effects of human error?
How can the risk be communicated with the people living in a possible flood path?

There is no clear bound to the possibilities of analysis, no clear guide as to what should be taken into account, no obvious definition of system elements, boundaries or measures. Though complexity, breadth and a lack of clarity, many modern problems differ significantly from traditional technical problems. At the same time, they are more difficult. Yet it is problems of this type that society is increasingly, and rightly, demanding that engineers should solve.

2.6.3 The Four Phases of Technology

To clarify ideas, Elms (1993) has thought of technology as developing in four phases. Each new phase includes those preceding it, but adds a new direction or dimension. Human have always used technology. Even the most primitive of our ancestors used tools, prepared food and medicines, and made artifacts such as pots, clothing or weapons, often with great skill and artistry. In this sense, technology has always been with us and has pervaded our lives. It still does, but with the essential and important difference that whereas once there was an immediate relation between humans and our physical surroundings, we are now part of a complex technology based web. The change
has been very great. It is really, from an engineers point of view as a change in the way they approach technology and decide how and for whom to carry out our the tasks.

Though historically the changes have been continuous, nevertheless it is helpful to regard them as occurring in four phases. The first phase can be called *Immediate Technology*. Once, if we wanted to eat, we had to hunt, plant crops or herd animals, depending on our culture. There was a simple connection between our fundamental needs and their attainment. The causal links were short and immediate. The tools required for phase 1 technology were simple and available to all, even though the technological products, such as cave painting or the manufacture of poisons for hunting, could be sophisticated.

Phase two, relates to urbanisation and so can be called *Urban Technology*, even though it was a technology that related to cities rather than one used exclusively by them. The growth of cities coincided with the need to centralise administrative power. The earliest probably resulted from the first use of extensive irrigation. This could not take place without the use of a massive communal effort to construct and maintain canals and other aspects of irrigation, which in turn required centralisation and a bureaucracy. Other reasons for the growth of cities were the need to control large political groupings, and trade. It should be remembered that, historically, cities were not always large it is believed, for instance, that at the earliest stage for which archaeological records are available, some of the Greek “cities” had a population of about 25 people.

In phase two technology, the immediacy of the link between technology and people’s needs was broken. Specialists built and manufactured, and mechanisms of trade developed. Technology was essential to the very existence of the growing web of society. However, the nature of technology was still quite different from modern practice, relating more to a combination of trade and artistry rather than to anything remotely like the engineering of today. Not that technology lacked sophistication—it was far from primitive. Significant advances took place in Europe, for instance, right through the dark ages and mediaeval times. However, construction and manufacture were still based mainly on rules of thumb rather than on rational analysis.

The third step, phase three *Rational Technology*, brings us to modern times. It coincides roughly with the development of the industrial revolution in Europe and the growing use of energy. For our purposes, the most important aspect of phase three was the growth of scientific rationalism and its adoption for engineering planning and design. This is the point at which professional engineering, as it is known, began to emerge. New analytic tools were developed, and engineering was no longer governed by arbitrary rules. The findings of science could be combined with measurements of material properties to allow
a faster and more reliable extension of existing technology into new artifacts and processes.

New branches of engineering came into being, such as aeronautics, electronics and tribology, and the movement was regularised and given added impetus by the developments of mass production and of national and international standards. The use of new energy sources, particularly those using fossil fuels, increased the role and capabilities of technology. And as society became increasingly urbanised, not only were people’s lives more dependent than ever on technology, but also the causal chains linking what they did with their fundamental needs became longer and more complex.

Nevertheless, there is a sense in which phase three technology is still simple, insofar as in its connectedness and its focus on the predictable and measurable it is straightforward. Causal chains are short, for the most part. As far as the analytic capabilities of engineers is concerned, technique has mostly emphasised the sophisticated analysis of relatively simple systems. For example, structural engineering deals with the analysis of individual structural elements at an increasing level of sophistication, particularly with the advent of modern computer codes. Yet the behaviour of an entire structure in an earth quake still cannot be modelled satisfactorily and, even if it could, there remains the underlying methodological problem that about 80 percent of failures are due to human error in design, construction or maintenance.

As another example of the limitation of phase three technology, consider electricity production and transmission. Thermal or hydro power stations can be designed remarkably efficiently, and sophisticated techniques exist for controlling transmission problems such as harmonics. Yet it seems far more difficult to plan for adequate supply capacity, or to evaluate alternatives as to their long-term effect on society or the natural environment. Techniques for handling such matters are primitive compared with those available for dealing with direct technical problems.

The existence of more complex problems and the growing need to deal with them Elms suggests that we are now entering a fourth phase. Technology is changing quickly and its persuasiveness continues to grow, and the speed of change is increasing. More important, though, and at the same time less obvious, is that at a deeper level the very nature of the technology-related problems society is trying to deal with are undergoing a fundamental change. As discussed in the previous section, the new problems are broader, more complex and less well-defined than those of phase three. They are pervasive and occur in all areas of engineering, and they are particularly characteristic of environmental
engineering in its broader sense. The new phase, phase four, can be called *Systems Technology*.

The discussion so far should not be taken to mean that complexity itself is new to technology. Rather, the point being made is that until recently, engineers have seldom needed systems approaches and that where they have been used, the results have generally been neither rigorous nor well founded.

### 2.6.4 Characteristic Weaknesses of Engineers

It is argued that engineers are not always very good at dealing with phase four problems. This is perhaps because engineering education for the most part deals with phase three problems, or because of self selection many engineers particularly enjoy technical problems. Let me set down a brief and personal list of our shortcomings. Though there are many exceptions, it is argued by Elms (1993) that engineers tend not to be as good as some other professional groups at:

- **Conceptual analysis**—Engineers are better with numbers, calculations and spatial perceptions than we are with abstract and loosely-defined ideas. If young engineers and lawyers are in action together, the difference in their ability to handle complex concepts is very marked. It is not that the engineers are unintelligent—far from it. But their training has not particularly fitted them for this type of analysis.

- **Communication**—Many engineering students are not particularly good at either written or oral communication, though for the most part they seem to attain reasonable skills in practice. The trouble may relate to conceptual analysis, both directly, as communication involves the systematic mustering of ideas, and indirectly, in that it has been found, for writing skills in English at least, that ability to write well correlates strongly with how many books are read.

- **Relating to other groups**—Engineers tend to be sure in their technical competence but are often less than tolerant of other groups and individuals who have a different approach, background or language.

- **Understanding limitations and underlying assumption**—Though the immediate technical limitations of a piece of analysis and the assumptions on which it is based are generally well appreciated. It is argued that engineers are not particularly good at understanding the deeper methodological and philosophical issues underlying their work. It may relate to conceptual analysis. For phase three problems, most of which cover technically well trodden ground, the problem is not especially important. However, it becomes more significant for the broader problems of phase four.
• **Leading complex projects**—Though many complex developmental projects are led by engineers, there are many more cases where management is taken over by other professions. In some areas, this seems to be an increasing trend. Engineers sometimes become leaders more because of their individual natures than by reason of their training.

### 2.6.5 Causes and Symptoms

Some problems outlined in the previous section are historical, some are attitudinal and some are educational, but all are interrelated. Many of the causes stem from an attitude of progress, development and exploitation, which arose particularly in the western world and accompanied its development of technology and its increasing use of and dependence on energy. The world was seen to be a limitless source of whatever was required. There was an emphasis on exploitation rather than sustainability, on competition at the expense of cooperation, on short planning horizons at a time of dynamic and seemingly perpetual change, and on seeing and working with simple unbounded systems, with no concerns about boundaries, of what lay beyond the fence, or of tomorrow. It was a period of increasing specialisation, first of the operators and workers of the industrial revolution, but later of engineers, doctors, lawyers and other professionals to the extent that we became rather like a hive of specialised insects, each with its place. And yet, anomalously, specialisation and change or, rather, the ability to adapt to it do not belong together. They are, ultimately, incompatible. Despite this, engineering education still seems to focus on specialisation with increasing proliferation of specialist subjects. The only restraints on this headlong progress and narrow focus seem to have been limitations of information processing capability, communication and time to respond to change through social and economic means.

To return to the historical approach of working with simple unbounded and, thus, improperly defined systems, it is heartening to see some determined attempts emerging to change to a different paradigm. The viewpoints and system visions of Don Roberts (1990) and John Peet (1992), among others, are particularly relevant.

One problem that has emerged is that engineers seem to have come to a position where there is an increasing lack of balance between technics and policy. Technical activities are increasingly out of control. Not only is political control uncertain at best, but we simply do not have adequate mechanisms and instruments for control, or any clear and agreed decision framework, despite the aims and results of the UNCED conference and Agenda 21.
The problems are ingrained and pervasive. They are also difficult, and they are grave in their possible results. Neither are they readily amenable to solution.

At the very least, though let's order our own house and educate engineers in such a way that our capability is improved and matched to the real needs that face us.

2.6.6 Requirements

So far, the discussion has considered problems. To deal with them, many things must be in place. Some are what the world needs, some our society. Others are the needs of engineers, either as individuals or as a profession.

There are three emergent needs that have to be addressed. The first is a need for control. Control on use and control on pollution. As this is a socio-political matter rather than one that can be dealt with by engineers, it is a requirement for understanding rather than for direct action. The second need is for sustainability, of life and resources of every sort, and here engineers are, surely, centrally involved. The third is for rehabilitation of damage, insofar as it can be achieved.

What, then, are the things engineers need to be able to do? In an arbitrary order, the items that have been identified by Elms (1993) are:

- the need to deal with complexity;
- the need to be able to take a long term view;
- the need for criteria against which to be able to assess proposals;
- the need for guiding principles of ethics, and equity;
- the need for an ability to relate and understand, beyond our immediate specialisations;
- the need to be aware of systems and their boundaries; and
- the need for an organising principle to integrate individual specialisations together.

The list is by no means complete. It does serve to illustrate, however, that if the modern beginning engineers has to have such capabilities, in addition to the more traditional technical skills we normally take for granted, then some very fundamental changes need to be made in engineering education.

2.6.7 A Change in Character

The chapter thus far has highlighted the need for a change in the character of engineering education, and engineering practice. This should not be taken to mean that all engineers
should be different. Roberts (1990), writing along similar lines, believes that about a quarter of engineers should be trained in the new and generalist way he outlines, with the rest applying themselves to more traditional tasks. This relates very well to the idea of the four phases of technology discussed earlier. Historically, when phase three technology came into being and professional engineers were needed, they still had to work with, and indeed needed, phase two trained people, that is, technicians and trades people. Similarly, phase four engineers need phase three professional engineers to deal with the more narrowly focused technical problems that, increasingly, are there to be solved.

Nevertheless, the profession as a whole must change in character. The change has been described elsewhere (Elms, 1989) as a search for wisdom, in contrast to knowledge. There is, of course, nothing wrong with acquiring knowledge. The phase four engineer must go further. The ideas of quality management are closely related to what the phase four engineer, and in this case, the environmentally educated engineer, needs to do. But, in addition, the new engineer needs strong communication skills, an ability to deal with large, complex and ill defined systems, and a clear and far sighted world view, which, together with a well developed ethical stance, more than anything else characterises phase four engineering wisdom.

2.7 Summary

The new environmentally sustainable educated engineers must be different in both skills and outlook. Tinkering with established subjects and course structures is no longer enough. That is why there is a need to re-examine the foundations, the fundamental early level courses for environmental engineering education that set the direction for the remainder of undergraduates. Many will want to change their outlook and acquire skills of the sorts that have been described. Thus, our “foundations” must embrace both undergraduate teaching and continuing engineering education. The next chapter will outline the philosophy whereby the interface between education, environmental problems and sustainability can be understood.
Chapter Three

Resources Survey

3.1 Introduction

This chapter outlines a philosophy whereby the interface between education, environmental problems and sustainability can be understood. It examines how the theories which stem from this philosophy have been developed and modified by a number of contemporary social scientists. This philosophy will map the future direction for the environmental education of engineers.

Over the first phase of the research a literature survey was conducted using on-line university library catalogues in Australia. This search was expanded to include the resources available at selected environmental research institutes in Australia, in particular the Environmental Research Institute at the University of New South Wales. It was quickly apparent that the amount of literature available specifically dealing with the environmental education of engineers was limited, with some notable exceptions. However the key books, journals and conference symposium were identified and assessed. It quickly became apparent that most of the literature available on the environmental education of engineers was quite recent and in most cases not particularly developed either theoretically or conceptually. Even international conferences on environmental education of engineers tended to consist of papers that were descriptive, outlining the situation as it existed in a particular institution.

The final phase of the literature review and resources review addressed the growing body of environmentally sustainable development, environmental education and environmental engineering information available over the internet. Again the amount of information that specifically dealt with the environmental education of engineers was minimal, much of the information was useful for background material, and more crucially served as models for future information dissemination and networking.

There is a diversity of approaches to environmental education in University level programs. This mainly has been caused by the autonomy of tertiary institutions and partly through increasing specialisation, both in basic academic studies and in areas of professional training. Different approaches have been used to relate specialist disciplinary studies to broader environmental issues, and to develop new interdisciplinary structures.
Yet among this complex collection of programs, each was a product of its own institutional situation, and only a few general patterns of approach were identified.

3.2 Environmental Education at Tertiary level: a Historical Background

The development of environmental education in Australian tertiary institutions during the last two decades has been extensive and diverse. The greater autonomy of tertiary institutions and the greater variety of specialist staff, courses and programs already established at these institutions have provided a basis for the diverse perspectives on environmental issues. Thus courses such as environmental law, environmental psychology, and even environmental musicology, which cannot be found anywhere in schools, have emerged in various universities and colleges throughout the country. And in a less dramatic way the emphasis in traditional science and social science courses has also shifted to encompass something of the ‘social responsibility’ movement so closely linked with many of the major environmental issues.

But associated with the greater diversity of such courses is the greater difficulty in reviewing them and the greater doubt in generalising from one course or institution to any other. Because of this it was impossible in the time to conduct a detailed survey of environmental education in tertiary institutions, and what follows is simply a selection of relevant examples to illustrate some of the more interesting and important trends. Nevertheless these examples were not chosen at random; they represent a systematic and fairly comprehensive analysis of course outlines from the handbooks of more than ninety institutions throughout Australia.

In discussing these examples it is convenient to separate undergraduate from postgraduate programs because of their different structure and purpose, and within the undergraduate programs to distinguish between individual courses or topics with some form of environmental orientation and whole degree or diploma programs leading to an award in some area of professional environmental activity. Since these programs are in many cases a composite of different environmental topics it is appropriate to consider first the individual topics, and later the more comprehensive programs at both undergraduate and postgraduate levels.

The environmental topics examined were of two types: the first, established disciplines and specialist areas intrinsically related to the human/environmental interaction theme but not necessarily to conservation, and the second, new disciplines or specialist areas emerging in response to the present environmental movement. The first category included such areas as agricultural science, biology, economics and geography, and a range of
specialist areas within each of these-agricultural economics, human ecology, urban geography and so on-that seemed particularly relevant to environmental education. In the general areas there were, as expected, numerous topics of environmental interest but relatively little explicit emphasis on conservational issues. In this respect it was in the specialist areas that the more significant developments in environmental education had occurred, and a few of these are worthy of comment.

In agricultural science there were several courses of particular environmental interest. One was a segment of agricultural botany at the University of New England which was modified in 1973 for inclusion as part of an undergraduate program in environmental science. This course emphasised the impact of environmental factors on plant growth and development and the ways in which some of these factors, such as rainfall, soil composition and air flow, could be manipulated to maintain and increase crop production and soil fertility. Another was a course in animal husbandry at the University of Sydney which aimed to give students an understanding of 'the interactions between man and animal in the domestication of farm animals and in the origin, distribution and economic importance of indigenous Australian mammals'. The third was a course in agricultural engineering at the University of Tasmania which dealt with, among other things, irrigation systems, characteristics of earth and rock fill dams, heat transfer and air conditioning in relation to glasshouse design, and so on. While none of these courses was necessarily concerned with the major international problems of overpopulation, energy production, pollution and resource depletion they were all concerned in some respect with long-term resource management, and thus with environmental education. It should also be mentioned that these courses were by no means the only examples in their respective subject areas; they were simply convenient examples on which sufficient information was available to confirm the major emphases.

There were many other courses in related areas of biological science that shared a similar environmental emphasis. For example, one of the forestry courses at the Australian National University, 'Harvesting and Utilisation of Forest Products', was developed in 1969 with the intention of giving students 'an understanding of industrial forestry and its social, economic and environmental implications'. The following examination questions from this course illustrate the importance given to this general aim:

1. Discuss possible effects on the environment of clear felling and logging dense stands of coniferous timber in country of very variable topography such that track-effectively. What measures should be taken in planning and control of the operation and in subsequent re-establishment of the forest to prevent long-term deterioration?(ANU, 1972)
2. Discuss the Australian fiberboard industry with reference to raw materials, location and pollution, and the importance of the industry to forest management. How is the development of a wood chip export industry likely to affect this importance? (ANU, 1971)

Likewise a course in marine biology at the University of Tasmania was intended to focus on the ways in which marine sciences could be used to regulate, and hence conserve, the very diverse and valuable ocean resources. And other courses in wildlife management, freshwater ecology and ecological physiology, also at the University of Tasmania, were all more or less concerned with aspects of environmental conservation.

Human biology, in particular human ecology, is perhaps the most important and most recent specialist area of environmental interest to develop in the biological sciences. By 1974 it had appeared in a number of institutions in as many different forms, including:

1. Human Biology, established in 1970 at Flinders University, and covering such topics as the consequences and control of population growth, food production and nutritional requirements, effects of various diseases and drugs, human evolution, population genetics, and so on.

2. Human Bioscience, established in 1973 at the University of New England to provide students, essentially humanities students with 'sufficient knowledge to allow them to make rational decisions concerning man's activities as they affect himself, society at large, the environment, and the future of mankind'.

3. Human Ecology and Human Adaptability, established in 1973 and 1974 respectively at the Australian National University, both 'concerned with the interplay between natural and cultural processes as they affect the total environment of man' and with 'the human response to environmental changes'.

Similar courses have also been established at almost every university and in numerous Colleges of Advanced Education throughout Australia (O'Neill, B & Boyden, S, 1972), all reflecting in their general aims the need for understanding the complex interrelationship between man and his physical, biological and social environment and for ensuring the effective long-term management of environmental resources.

In the physical sciences, too, there were a few courses of particular relevance to environmental education. One of these was 'Physics and Modern Man', a course established for humanities students at Flinders University to enable them to gain 'an
understanding of some of the major concepts and developments in physics and to relate these to social, political and philosophical aspects of society'. The topics covered included, among other things, the use of electromagnetic radiation in communication systems, the atmosphere and atmospheric pollution, the use of radioisotopes in medicine and industry, and the problem of limited world resources of energy. Another course of a similar kind was environmental chemistry at Adelaide College of Advanced Education, which examined various aspects of chemical pollution and ways in which chemicals could be used in reducing or preventing disease, improving soil fertility and crop production, increasing the efficiency of manufacturing processes and so on. Again these courses were just isolated examples of a common and increasing trend throughout Australia toward formal recognition of the social and environmental implications of science and technology. However this trend was not without some reaction in a physics course on ‘waves’ at James Cook University the ‘environmental’ component, dealing essentially with the characteristics and effects of noise was claimed by the course coordinator in 1973 to have been poorly received by the students and was therefore to be replaced in the following year with a more theoretical section on optics. This was not, however, the typical student response, and in fact all of the other courses examined were planned by the course coordinators to either continued or expanded in subsequent years.

Among the other specialist courses of particular environmental interest were such things as urban geography, town planning and mining engineering, all of which were intrinsically concerned with some aspect of interaction between man and environment and in most cases also provided some emphasis on conservational issues, though this was not necessarily their central theme. However there was another group of specialist courses, smaller in number, more diverse in character and more centrally concerned with the conservation theme, that seemed to have developed as a direct result of the environmental movement and represented quite new applications of well established disciplines. These courses include:

1. Environmental Psychology, examining the psychological effects of crowding, the need for privacy, reactions to different types of architectural design, attitudes to population growth and control, behavioural correlation of malnutrition, and so on;

2. Environmental Law, designed to give students an understanding of the role played by law in dealing with problems whether local, national or international of pollution, resource development and exploitation; and
3. Environmental Musicology, designed ‘to sensitise people to the sounds around them and make them aware of the need to preserve those sounds that give pleasure and to reduce those that do not’.

Courses such as these have now emerged in a number of tertiary institutions, each having its own peculiar emphasis but sharing a general and fundamental theme of human/environmental interaction and, in most cases, a clear and consistent conservationist approach.

There is one further group of courses that seems worthy of special comment. This is the category of interdisciplinary courses, also recent in origin, diverse in character and centrally concerned with environmental and in particular conservational issues. Two examples should serve to illustrate the nature and potential diversity of these courses. The first, ‘The Ecology of Man and Society’, was established in 1974 at Flinders University in an attempt to provide a broad analysis of ‘the physical and cultural factors which affect the relationship between man and his environment’, drawing upon basic principles from biology, earth sciences, economics, geography and politics. The major themes developed in this course included:

- General principles of ecology and interactions within ecosystems;
- the cultural evolution of man; history of man’s concern for the environment;
- population growth and dynamics; resource availability and control; waste disposal;
- relationship between economic system and environmental problems; political causes of current and impending eco-crisis;
- the ecological contradictions inherent in state and corporate capitalism;
- political consequences of the range of proposed solutions;
- the long term effects of economic growth on consumption of natural resources;
- the implications of a stationary state on economic organization (Flinders University, 1974).

The second example, ‘The Environmental Situation’, was a course introduced in 1973 at the University of New South Wales for students of various academic backgrounds, including library studies, town planning, sociology, and physical and biological sciences in an attempt to broaden their perspective in their consideration of major environmental issues. The assessment of this course, as well as most of the course content, was based on a series of research projects undertaken by the students on approved ‘environmental’ topics. To encourage diversification of interests the following instruction was given to the students: ‘Since the course is interdisciplinary in aim and content special credit will be given to students who venture beyond their academic background and attempt to pursue or to create multidisciplinary lines of enquiry.’ (UNSW, 1973) The range of issues
actually covered in the student projects presented in Table 3.1 illustrates clearly the intended interdisciplinary perspective of the course and the diversity of academic backgrounds from which the students came.

There have been many other such courses established throughout Australia, and while each has involved its own characteristic range of perspectives and topics they have all been centrally concerned with environmental issues and have emphasised long-term environmental management. In this respect they probably represent a more substantial attempt at developing environmental education, partly because of their broader perspective, partly because of their common emphasis on practical research and development projects—that is, on the involvement of students in particular local community issues. In these courses, the students have been able and encouraged to learn from each other, and in doing so to accept a diversity of views and to balance opposing attitudes and values from among people with firm and rationally based opposing attitudes and values from among people with firm and rationally based commitments but who do not necessarily share the same conservationist ideals.

Cooperative learning has probably been one of the most important aims of interdisciplinary courses, not only in environmental studies but also in other areas, and it has been given even greater prominence in the more comprehensive degree and diploma programs. Such programs have now been established at a number of colleges and universities throughout Australia, and despite their common purpose of training students for professional careers in the management of environmental resources they differ substantially in structure and content. Certain general features are, however, shared by a number of these programs, and with respect to these it is convenient to discuss separately those at the undergraduate and those at the postgraduate levels. Again this discussion will focus on only a few of the many possible examples, though these should suffice to illustrate the more common and important trends.

At the undergraduate level most of the programs examined reflected an attempt to establish some compromise between the need for disciplinary specialisation to achieve academic sophistication or respectability and the desire to broaden the students’ perspective through a more holistic and therefore, to some extent, academically superficial consideration of environmental issues. The usual pattern was therefore a combination of one or two ‘major’ studies, following a three year sequence with progressive specialisation, though not necessarily encompassing an entire discipline or confined to any single discipline, together with a fairly broad range of ‘minor’ studies including both relevant disciplinary courses and interdisciplinary courses centred around particular environmental topics.
This pattern is perhaps best illustrated by referring to descriptions of some of the established programs. The first relates to the degree in Natural Resources established in 1971 at the University of New England:

It is built on a common core of basic courses in biological sciences, physical sciences, social sciences, and mathematics which develops into a special study of ecosystem analysis and its applications in various resource management areas. In the senior years options in science, management and technology topics are provided to allow for some degree of specialisation in a range of fields which include hydrology, soil conservation, wildlife management, national park management, water quality management, resource survey and land use planning. The degree provides a professional basis for careers in water and soil conservation departments, land management agencies, national park and wildlife management services, regional planning and environmental control organisations, environmental investigation and consulting groups, and many fields of research, teaching and government administration (University New England, 1973).

This was one of the first undergraduate programs in environmental studies to be established in Australia and has been followed by many others with a broadly similar purposes and structure. One of these was the Diploma of Applied Science in Natural Resources conducted at Roseworthy Agricultural College commencing in 1977.

The Diploma course in Natural Resources provides training in the basic sciences, their application to the management, assessment and interpretation of natural resources, and the sociological, legal and economic implications of natural resource management. A major theme of the course is the appreciation and resolution of the conflicts known to develop between groups which advocate different uses for natural resources.

During the first year of the course students undertake studies in the basic sciences related to natural resources, including biology, biochemistry, chemistry, earth science, economics and sociology. Studies in the second and third years are undertaken in the following areas:

(1) Ecology
(2) Natural resources science and management
(3) Natural resources methodology including flora and fauna; geology; exotics; remote sensing, cartography and surveying; sampling; physical environment; interpretation and recreation; engineering and fire control.
The course includes a number of other elective subjects, and students are also required to complete an individual study project related to their elective (Roseworthy Agricultural College, 1977).

Other undergraduate programs have differed in the range of component courses in particular those of a specialist nature, whether disciplinary or topic based but not in the major contributing disciplines or in the basic structure of major and minor sequences. Even in teacher training programs where a generalist background might be expected to hold the highest priority for subsequent teaching of interdisciplinary courses at primary and secondary levels, the need for some degree of specialisation has invariably been recognised, if only to provide students with a wider range of potential teaching areas and alternative employment prospects. However this has not seriously limited the opportunities for students to explore a wide range of important environmental topics and relevant contributing disciplines. An example of this, still within the constraints of a major study sequence required as part of the program, is provided in the following description of the Bachelor of Education program in Environmental Studies at Rusden State College in Victoria, which was first established in 1973.

Students may take a double major from the three subjects offered by the Environmental Studies Department (biology, geography, physical science) or combine any one of these with a major study from another Department, for example, economics, psychology, sociology, legal studies. The course in years three and four is completely unitised and offers a wide choice of units. For some students in years three and four the preference is for fairly traditional biology, geography or physical science units and thus the course may produce a subject specialist.

For other students there is a preference for more environmentally oriented units. Rather than the traditional units such as developmental biology, geomorphology, selected Australian animal groups, analytical chemistry, etc., the student can choose units such as environmental education and the community, coastal conservation, the packaging industry, recreational planning, energy, etc. Some of these units are offered within subject areas whereas others are offered by the Department as a whole, as an interdisciplinary unit. These environmentally oriented units may be taken as part of a biology, geography or physical science major, and are taken by approximately half the students (Stokes, 1976).

It is interesting to note that in all of these programs there has at least been one prescribed component from the life sciences usually ecology, physical sciences usually chemistry.
and social sciences, sociology, geography, or perhaps psychology. The same pattern was evident in most of the interdisciplinary courses examined at the secondary level, and in the few that did not involve biology this was mentioned by both staff and students as an important deficiency. Thus there seems to have evolved in these interdisciplinary courses, irrespective of level, purpose, teaching approach and the range of environmental topics considered, some consensus on the basic contributing disciplines and on the need for an in-depth understanding of at least some disciplinary principles, however superficial the knowledge of others.

The need for specialisation has not been so apparent in the postgraduate environmental studies programs. It has generally been assumed that the students in these programs, most of whom would already have been employed in areas related to environmental management would have sufficient specialist knowledge to cope with certain disciplinary aspects of environmental problems but would require a broader perspective to see how other disciplines or professions might also contribute toward solving the same problems. Thus the general pattern in postgraduate programs has been to encourage students to extend their disciplinary knowledge into areas not covered in their former degree programs and to apply their knowledge, both specialised from former studies and professional experience and relatively superficial from courses taken as part of the environmental studies program, to a particular community problem. The following comment on the graduate diploma in environmental studies at Macquarie University established in 1973 is typical of the approach adopted in most of the postgraduate programs:

The aim of the Diploma in Environmental Studies is to give people of widely differing backgrounds the opportunity of widening their knowledge of environmental issues and, by interchange of ideas and studying particular systems to arrive at more effective ways of solving current problems. Every opportunity is given to encourage the interplay of ideas both between and among the students and staff in a rigorous and disciplined manner. The experience is planned to be broadening, attempting to break down the barriers between specialists in an area of major social concern involving all areas of knowledge in Table 3.1.

A particular feature of this course was the opportunity to participate in, and develop approaches to, the assessment of proposed actions on the environment (Deer, 1974). There are two characteristics shared by all the postgraduate environmental studies programs established to date: the first is an emphasis on practical application of theoretical principles to real environmental problems, this has usually been the major basis of assessment and the second is the encouragement of students to work together in specialist
teams. The emphasis on practical problem solving has not been peculiar to postgraduate programs. Indeed, it has also been a component of most of the undergraduate degree and diploma programs, and even of some of the individual topic courses, both disciplinary and interdisciplinary. Nor is it peculiar to the area of environmental studies, but the kinds of problems examined in these programs have been characteristic in their focus on conservational issues, however broadly interpreted, and have formed a much more

Table 3.1. List of Student Research Projects for ‘The Environmental Situation’, Department of General Studies, University of New South Wales, 1973

<table>
<thead>
<tr>
<th>Degree Program</th>
<th>Title of Research Project</th>
</tr>
</thead>
<tbody>
<tr>
<td>Applied Geology</td>
<td>Environmental effects of extraction of minerals-what can be done?</td>
</tr>
<tr>
<td>Architecture</td>
<td>The relation between art and the behavioural sciences and whether this can have positive environmental effects</td>
</tr>
<tr>
<td>Architecture</td>
<td>The parameters acting to limit the density at which people can live</td>
</tr>
<tr>
<td>Architecture</td>
<td>Conservation of the built environment: why, what, how and by whom? Some case studies</td>
</tr>
<tr>
<td>Architecture</td>
<td>Social welfare homes for children: child’s needs in an institution, field study in Sydney, some decisions for environments</td>
</tr>
<tr>
<td>Architecture</td>
<td>Psychology of enclosure and the dome environment</td>
</tr>
<tr>
<td>Architecture</td>
<td>Integrated study of three topics: relationship between mobility and land usage; planning for more diverse communities; more efficient use of materials in building</td>
</tr>
<tr>
<td>Architecture</td>
<td>An observation and expression of our environmental attitudes-a film</td>
</tr>
<tr>
<td>Civil Engineering</td>
<td>Eugenics: controlling the future of man</td>
</tr>
<tr>
<td>Electrical Engineering</td>
<td>Colour and its effects on us: cars, buildings, advertising, and the media</td>
</tr>
<tr>
<td>Geology</td>
<td>The effects of carbon dioxide, aerosols, and other atmospheric pollutants on the global climate</td>
</tr>
<tr>
<td>Medicine</td>
<td>Coronary heart disease: the influence of lifestyle. An examination of New South Wales statistics</td>
</tr>
<tr>
<td>Science</td>
<td>Colour therapy and related topics: psychological effects of colour rearrangement, mechanisms of colour choice, potential of environments as a modifier of life styles</td>
</tr>
<tr>
<td>Social Work</td>
<td>Political decision making processes and the environment</td>
</tr>
<tr>
<td>Textile Technology</td>
<td>Nationalism and the world environment</td>
</tr>
<tr>
<td>Textile Technology</td>
<td>The change in housing needs at various times of life: how to create a satisfactory living environment</td>
</tr>
<tr>
<td>Town Planning</td>
<td>Past Australian attitudes toward development and their relevance to present-day environmental attitudes</td>
</tr>
<tr>
<td>Town Planning</td>
<td>Water pollution: legislation and control, using the Parramatta River as a case study</td>
</tr>
<tr>
<td>Social Work</td>
<td>Concepts of communication of the environment to the community: communication theory, over seas experience, local factors</td>
</tr>
</tbody>
</table>

important component in postgraduate than in undergraduate programs. On the latter point the assessment weighting given to the research project report has invariably been one-third or more of the overall program assessment, and in most, if not all cases, a satisfactory report has been a condition for receiving the award. On the former point, the following list of research proposals Figure 3.1 from students in the Master of
Environmental Studies program at the University of Adelaide illustrates both the diversity of topics and the similarity of conservational focus characteristic of environmental studies programs.

<table>
<thead>
<tr>
<th>Title of research proposals</th>
</tr>
</thead>
<tbody>
<tr>
<td>• The assessment and management of heritage property.</td>
</tr>
<tr>
<td>• The economics of vegetation clearance.</td>
</tr>
<tr>
<td>• The effectiveness of small islands of vegetation as wildlife habitats.</td>
</tr>
<tr>
<td>• History of environmental management of the River Murray in South Australia.</td>
</tr>
<tr>
<td>• Some environmental implications of the climate of Mount Barker.</td>
</tr>
<tr>
<td>• The evaluation of seismic risk with particular reference to the environmental management of seismic hazard and to the social, economic and legal implications of earthquake forecasting.</td>
</tr>
<tr>
<td>• Perception of environmental quality in southwest Adelaide: implications for urban planning.</td>
</tr>
<tr>
<td>• Environment, education, and South Australia’s teachers—values in conflict?</td>
</tr>
</tbody>
</table>

Clearly topics such as these cannot be covered adequately from a single disciplinary perspective, and it is in part this need for a broader analytical view which has led to the common emphasis on teamwork in postgraduate environmental studies programs. Even this, however, has been approached in many different ways. For example, in the University of Adelaide program the students have tended to work individually, contrary to the policy suggested in the degree schedule but with joint staff supervisors from different academic departments, or in some cases with one of the supervisors from an outside organisation such as the state Department for the Environment. The project reports have also reflected the work of individual students, but with acknowledgment of the work of other students in related areas: ‘The research project will normally require the co-operative effort of several students; however, each student must present a separate dissertation of a standard acceptable to examiners appointed by the Board. The dissertation must not only deal with those aspects of the project studied by the student, but must also indicate an appreciation of the work of other students undertaking the project’ (University Adelaide, 1978).

By contrast with this, in the Master of Environmental Science program at Monash University most of the students have worked together in groups of four to six on a
common research problem, with each student coming from a different academic background and examining a different aspect of the problem. These groups have submitted both a joint report and separate dissertations from individual students, though the latter may have in part a jointly written introduction and concluding discussion. This has caused some difficulties in examining the respective contributions of particular group members but at the same time reflects a more realistic approach to the solving of real and complex environmental problems.

Apart from the common emphasis on broadening the basis of academic background and on practical application and teamwork, there has also been some similarity among postgraduate programs in the range of topics or courses available. Usually they include options on legal and political, economic, ecological, sociological and psychological aspects of environmental issues. The program are structured with a variable division between coursework and research components, both mandatory. They provide for a wide range of options, and the use of teaching staff from outside organisations such as government departments, CSIRO, commercial and industrial organisations. Because of the practical constraints already discussed, it has not been possible in this section to present more than a superficial view of some of the major trends in tertiary level environmental education. By and large these have been similar to the overseas trends. Slower to emerge, perhaps, but no less significant in their impact and in their promise for future developments. However the future of environmental studies will to a large extent be determined by more general pressures on educational institutions, and at present these point to a reduction rather than expansion in curriculum offerings. At least one of the environmental studies programs at the University of Adelaide has already come under review to determine whether it should be continued beyond the present student commitment, but there seems as yet no general decline in demand for such programs and the demonstrated but not unqualified success of the more established ones indicates a reasonably secure position for environmental studies programs in tertiary institutions.

3.3 Categorising Tertiary Environmental Education in Australia

Since the late 1980s governments have become conscious of the potential for tertiary environmental education to play a greater role in movements towards sustainable forms of development. In Australia various Conservation Strategies and the Ecologically Sustainable Development process have suggested that environmental education should have a higher profile at tertiary institutions (Victorian Government 1987, Commonwealth of Australia 1992).
It is clear that tertiary environmental education activity has been expanding and government rhetoric is lending support to that expansion, but the picture of environmental education at tertiary institution in Australia is a confusing one. Courses appear to have developed in an ad hoc way very much according to the enthusiasm and interests of individual academics or groups of academics. Courses are taught from within a range of traditional disciplinary areas and the concept of what constitutes an ‘environmental course’ varies. Greenfield’s (1993) directory of Australian courses categorised environmental courses into 19 types suggesting that the scope of what was seen as an environmental course was expanding or, more worryingly, becoming fragmented.

This work, based on a survey of environmental courses in Australia using ‘Net pages’, builds on the work done by the author recently, by looking at the kinds of courses which have been developed, what characterises them, and what the employment prospects are for graduates. The results provide a broad picture of the courses to all involved in environmental education. The final sections present some thoughts on the directions of tertiary environmental education which it is suggested need to be considered by the educators and all those concerned about the field.

3.3.1 The study and its results

There is no ‘clearing house’ for environmental courses and because they are taught from within a range of academic faculties even academics teaching in the field lack information about other similar courses. Guides such as Cockburn et al. (1995), Greenfield (1993), Victorian Association for Environmental Education (1994) and the information accessed through ‘Net pages’, particularly EnviroNet (1999) provide a starting point for prospective students, but may not provide much insight into the characteristics of a course. The survey reported here had the principal objectives of gaining a more accurate picture of the evolving field of tertiary environmental education and of complementing the information contained in the recent guides. A secondary interest was to see how environmental courses defined themselves through their practice.

The term ‘environmental course’ was taken broadly to include those courses with ‘environment(al)’ in their title, and those which contained an identifiable environmental stream of study; this included degrees in Arts, Education, Engineering, Science and Social Science. The survey was targeted at all full degree courses, rather than at individual ‘environmental’ subjects. In total about 150 undergraduate and postgraduate courses were identified and surveyed.
The courses were categorised into four groups; the numbers of courses within each were as follows:

- Environmental Studies, which included courses with titles incorporating planning, design and heritage-8 undergraduate, 8 postgraduate
- Environmental Science, which included courses with title incorporating applied science, management, recreation, health-29 undergraduate, 7 postgraduate
- Environmental Engineering-18 undergraduate, 18 postgraduate
- Environmental Education-2 undergraduate, 2 postgraduate

The generic tertiary level of courses ranged from Advanced Certificate to PhD; the number of courses at each level from fifty seven institutions was as follows Figure 3.2:

<table>
<thead>
<tr>
<th>Level of course</th>
<th>Type of course</th>
<th>Number of courses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Undergraduate</td>
<td>Advanced Certificate</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Associate Diploma</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Major stream of a Bachelor degree</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Bachelor degree</td>
<td>49</td>
</tr>
<tr>
<td>Postgraduate</td>
<td>Graduate Diploma</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Graduate Diploma/Masters</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Masters</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>PhD</td>
<td>12</td>
</tr>
</tbody>
</table>

Figure 3.2 Number and type of courses at different level of study

These were grouped under the four categories of environmental courses as a convenient way of gaining an overview of the range of courses, and to help identify differences in the kinds of courses.

To begin with a general indication of the size and history of the courses was obtained through identifying the year in which each commenced and the size of the first year intake. The numbers of courses starting in the three decades are shown in Table 3.2. The results indicate that courses starting in the 1990s generally had a smaller intake than the longer established courses. Also there has been a strong growth in the number of
environmental science and engineering courses, especially in the 1980s and 1990s, while a small increase in environmental studies and education courses has occurred.

The ‘mini explosion’ of science/engineering courses raises questions about the pace of development of environmental courses and whether this indicates merely a reworking and renaming of existing disciplinary courses.

Table 3.2. Number of environmental courses beginning in Australia the period 1950-1990

<table>
<thead>
<tr>
<th>Course type</th>
<th>Started in</th>
<th>1950s</th>
<th>1980s</th>
<th>1990s</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Environmental Studies</td>
<td>Undergraduate</td>
<td>3</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Postgraduate</td>
<td>5</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Environmental Science</td>
<td>Undergraduate</td>
<td>5</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Postgraduate</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Environmental Engineering</td>
<td>Undergraduate</td>
<td>-</td>
<td>-</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>Postgraduate</td>
<td>-</td>
<td>-</td>
<td>18</td>
</tr>
<tr>
<td>Environmental Education</td>
<td>Undergraduate</td>
<td>-</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Postgraduate</td>
<td>-</td>
<td>-</td>
<td>2</td>
</tr>
</tbody>
</table>

Section 2 of the study concentrated on gaining an understanding of the characteristics and directions of environmental focus, the meaning of the term ‘environment’, and about each course’s philosophy. The results indicate whether and how the course sought to incorporate the approaches of different disciplines. The results are presented in Table 3.3.

Table 3.3. Course disciplinary focus

<table>
<thead>
<tr>
<th>Course type</th>
<th>Disciplinary focus</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>S</td>
</tr>
<tr>
<td>Environmental Studies</td>
<td></td>
</tr>
<tr>
<td>Undergraduate</td>
<td>-</td>
</tr>
<tr>
<td>Postgraduate</td>
<td>1</td>
</tr>
<tr>
<td>Environmental Science</td>
<td></td>
</tr>
<tr>
<td>Undergraduate</td>
<td>4</td>
</tr>
<tr>
<td>Postgraduate</td>
<td>1</td>
</tr>
<tr>
<td>Environmental Engineering</td>
<td>13</td>
</tr>
<tr>
<td>Undergraduate</td>
<td>-</td>
</tr>
<tr>
<td>Postgraduate</td>
<td>-</td>
</tr>
</tbody>
</table>

Key:
S : Singledisciplinary focus    M : Multidisciplinary focus
C : Crossdisciplinary focus    I : Interdisciplinary focus
T : Transdisciplinary focus
Additional insight into the breadth and complexity of the categories of environmental courses was gained by considering interpretations of the concept of ‘environment’. This explored through the different definitions of term ‘environment’; a summary of definitions shown in Table 3.4.

Table 3.4. Definitions of ‘environment’

<table>
<thead>
<tr>
<th>Course type</th>
<th>Definitions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmental Studies</td>
<td></td>
</tr>
<tr>
<td>Undergraduate</td>
<td>• Interconnections of natural, social and personal worlds</td>
</tr>
<tr>
<td></td>
<td>• Influences which comprise a context for humans’ environments</td>
</tr>
<tr>
<td>Postgraduate</td>
<td>• ecological and human systems</td>
</tr>
<tr>
<td></td>
<td>• interactions of humans with their surroundings</td>
</tr>
<tr>
<td>Environmental Science</td>
<td></td>
</tr>
<tr>
<td>Undergraduate</td>
<td>• biophysical elements</td>
</tr>
<tr>
<td></td>
<td>• interaction of physical factors with recognition of humans in physical systems</td>
</tr>
<tr>
<td>Postgraduate</td>
<td>• natural, built/occupational environments</td>
</tr>
<tr>
<td></td>
<td>• context of individuals’ and societies’ actions</td>
</tr>
<tr>
<td>Environmental Engineering</td>
<td></td>
</tr>
<tr>
<td>Undergraduate</td>
<td>• national environment</td>
</tr>
<tr>
<td></td>
<td>• as per the Institution of Engineers Australia</td>
</tr>
<tr>
<td>Postgraduate</td>
<td>-</td>
</tr>
<tr>
<td>Environmental Education</td>
<td></td>
</tr>
<tr>
<td>Undergraduate</td>
<td>• natural world and its relationship with humans</td>
</tr>
<tr>
<td>Postgraduate</td>
<td>• biological, cultural and historical</td>
</tr>
</tbody>
</table>

In order to discover whether there were differences in the focuses of the courses, outlines of the philosophy of the courses investigated. A summary of these contained in Table 3.5.

The teaching approaches adopted in a course was another element which might have helped to distinguish between environmental courses. Table 3.6 presents a summary of the assessment of the teaching approaches adopted as ascertained from the documentation.
**Table 3.5. Philosophy of course**

<table>
<thead>
<tr>
<th>Course type</th>
<th>Main philosophy of the courses</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Environmental Studies</strong></td>
<td></td>
</tr>
<tr>
<td>Undergraduate</td>
<td>• provide an environmental qualification and understanding of environmental management issues</td>
</tr>
<tr>
<td></td>
<td>• develop understanding of social context and complexity of environmental problems and operate in</td>
</tr>
<tr>
<td></td>
<td>interdisciplinary teams</td>
</tr>
<tr>
<td>Postgraduate</td>
<td>• provide enhanced knowledge in environmental science/management policy</td>
</tr>
<tr>
<td></td>
<td>• develop understanding of biophysical and social components</td>
</tr>
<tr>
<td></td>
<td>• enable a balanced analytical appraisal of environmental issues and enhance environmental</td>
</tr>
<tr>
<td></td>
<td>values</td>
</tr>
<tr>
<td><strong>Environmental Science</strong></td>
<td></td>
</tr>
<tr>
<td>Undergraduate</td>
<td>• provide professional education</td>
</tr>
<tr>
<td></td>
<td>• meet industry and community needs</td>
</tr>
<tr>
<td></td>
<td>• sustainable human environment interaction is possible if impacts can be measured</td>
</tr>
<tr>
<td>Postgraduate</td>
<td>• improve understanding outside previous science training</td>
</tr>
<tr>
<td></td>
<td>• provide solutions involving social and physical elements</td>
</tr>
<tr>
<td><strong>Environmental Engineering</strong></td>
<td></td>
</tr>
<tr>
<td>Undergraduate</td>
<td>• reconcile engineering and the environment</td>
</tr>
<tr>
<td></td>
<td>• provide a rational basis for decision making regarding human environment impacts</td>
</tr>
<tr>
<td>Postgraduate</td>
<td>-</td>
</tr>
<tr>
<td><strong>Environmental Education</strong></td>
<td></td>
</tr>
<tr>
<td>Undergraduate</td>
<td>• appreciate an ecological paradigm</td>
</tr>
<tr>
<td>Postgraduate</td>
<td>• train and equip people working in environmental education</td>
</tr>
</tbody>
</table>

**Table 3.6. Teaching and assessment approaches**

<table>
<thead>
<tr>
<th>Course type</th>
<th>Main assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Environmental Studies</strong></td>
<td></td>
</tr>
<tr>
<td>Undergraduate</td>
<td>• group problem solving</td>
</tr>
<tr>
<td></td>
<td>• experiential learning</td>
</tr>
<tr>
<td></td>
<td>• workshops/seminars</td>
</tr>
<tr>
<td></td>
<td>• studios/project work</td>
</tr>
<tr>
<td>Postgraduate</td>
<td>• lectures, tutorials and seminars</td>
</tr>
<tr>
<td></td>
<td>• workshops</td>
</tr>
<tr>
<td></td>
<td>• field studies</td>
</tr>
<tr>
<td></td>
<td>• group projects</td>
</tr>
<tr>
<td></td>
<td>• research thesis/project</td>
</tr>
<tr>
<td></td>
<td>• computer based projects</td>
</tr>
<tr>
<td><strong>Environmental Science</strong></td>
<td></td>
</tr>
<tr>
<td>Undergraduate</td>
<td>• lectures and practical sessions #</td>
</tr>
<tr>
<td></td>
<td>• field work #</td>
</tr>
<tr>
<td></td>
<td>• projects</td>
</tr>
<tr>
<td></td>
<td>• group work</td>
</tr>
<tr>
<td>Postgraduate</td>
<td>• lectures/seminars #</td>
</tr>
<tr>
<td></td>
<td>• research project #</td>
</tr>
<tr>
<td></td>
<td>• group work</td>
</tr>
<tr>
<td></td>
<td>• field work</td>
</tr>
<tr>
<td><strong>Environmental Engineering</strong></td>
<td></td>
</tr>
<tr>
<td>Undergraduate</td>
<td>• lectures, tutorials, laboratory and practical sessions #</td>
</tr>
<tr>
<td></td>
<td>• group work</td>
</tr>
<tr>
<td>Postgraduate</td>
<td>-</td>
</tr>
<tr>
<td><strong>Environmental Education</strong></td>
<td></td>
</tr>
<tr>
<td>Undergraduate</td>
<td>• participatory environment</td>
</tr>
<tr>
<td>Postgraduate</td>
<td>• cooperation, social criticism and reflection</td>
</tr>
<tr>
<td></td>
<td>• learning by doing</td>
</tr>
</tbody>
</table>

# most frequently mentioned
Focus, philosophy and teaching approaches among other influences can all be expected to produce a variety of competencies in the graduates of the four kinds of environmental courses. Table 3.7 presents the graduates’ competencies as identified.

<table>
<thead>
<tr>
<th>Course type</th>
<th>Main skills/abilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmental Studies</td>
<td></td>
</tr>
<tr>
<td>Undergraduate</td>
<td>• research #</td>
</tr>
<tr>
<td></td>
<td>• group work #</td>
</tr>
<tr>
<td></td>
<td>• contextual understanding of environment #</td>
</tr>
<tr>
<td></td>
<td>• interdisciplinary understanding</td>
</tr>
<tr>
<td></td>
<td>• analytical problem solving</td>
</tr>
<tr>
<td>Postgraduate</td>
<td>• communication skills #</td>
</tr>
<tr>
<td></td>
<td>• analytical #</td>
</tr>
<tr>
<td></td>
<td>• integrative #</td>
</tr>
<tr>
<td></td>
<td>• group work #</td>
</tr>
<tr>
<td></td>
<td>• range of disciplinary understandings #</td>
</tr>
<tr>
<td></td>
<td>• scientific approach #</td>
</tr>
<tr>
<td></td>
<td>• practical</td>
</tr>
<tr>
<td></td>
<td>• problem solving</td>
</tr>
<tr>
<td>Environmental Science</td>
<td></td>
</tr>
<tr>
<td>Undergraduate</td>
<td>• disciplinary competency #</td>
</tr>
<tr>
<td></td>
<td>• communication skills #</td>
</tr>
<tr>
<td></td>
<td>• practical</td>
</tr>
<tr>
<td></td>
<td>• problem solving</td>
</tr>
<tr>
<td></td>
<td>• analytical #</td>
</tr>
<tr>
<td></td>
<td>• holistic #</td>
</tr>
<tr>
<td></td>
<td>• multi/interdisciplinary understanding</td>
</tr>
<tr>
<td></td>
<td>• technical competency</td>
</tr>
<tr>
<td>Postgraduate</td>
<td>• critical, investigatory skills</td>
</tr>
<tr>
<td></td>
<td>• scientific knowledge</td>
</tr>
<tr>
<td></td>
<td>• integrative ability</td>
</tr>
<tr>
<td></td>
<td>• multi-disciplinary perspective</td>
</tr>
<tr>
<td></td>
<td>• problem solving</td>
</tr>
<tr>
<td>Environmental Engineering</td>
<td></td>
</tr>
<tr>
<td>Undergraduate</td>
<td>• making rational decisions with limited knowledge</td>
</tr>
<tr>
<td></td>
<td>• communication skills</td>
</tr>
<tr>
<td></td>
<td>• technical competency</td>
</tr>
<tr>
<td></td>
<td>• problem solving</td>
</tr>
<tr>
<td></td>
<td>• multi-disciplinary understanding</td>
</tr>
<tr>
<td>Postgraduate</td>
<td></td>
</tr>
<tr>
<td>Environmental Education</td>
<td></td>
</tr>
<tr>
<td>Undergraduate</td>
<td>• critical empowerment</td>
</tr>
<tr>
<td></td>
<td>• intuitive awareness</td>
</tr>
<tr>
<td>Postgraduate</td>
<td>• facilitate social change</td>
</tr>
<tr>
<td></td>
<td>• coordinate the energy of community groups</td>
</tr>
<tr>
<td></td>
<td>• communicate environmental messages</td>
</tr>
<tr>
<td></td>
<td>• teaching competency</td>
</tr>
</tbody>
</table>

# most frequently mentioned
3.3.2 Discussion

Data collected above do not provide insight into the forces which led to the variety observed in environmental courses. Remaining open to speculation are the effects of a series of factors including the role of the disciplinary area or department which spawned the course, the personal interests of the initial and subsequent staff, changing interests of students, the developing educational experiences of students in secondary schools, changing staffing and research needs of government and private industry, influence of the reported state of the global environment, the needs of international students and the effects of amalgamations and rationalisation within the tertiary sector.

There has been a substantial growth in the number of environmental courses over the past two decades, particularly in the areas of Environmental Science and more recently in Environmental Engineering. Environmental Studies courses have remained small in number as have Environmental Education courses.

The structures and content of tertiary environmental courses surveyed were varied and complex; tertiary environmental education might be seen as lacking coherence and clear direction. The emphasis was on environmental science and environmental engineering, with some of the later courses in environmental science and environmental engineering appearing to be renamed versions of other science and engineering courses. The apparent conversion of courses from science and engineering to environmental science and environmental engineering might be seen as a reaction to the reduced interest from secondary school students in traditional science and engineering courses and as an attempt to attract students by 'cashing in' on the great surge of interest in environmental matters of the late 1980s and early 1990s.

Course descriptions presented by Cockburn et al. (1995) tended to reinforce this observation as there were few indications of adequate coverage of social constructions of science, engineering or environment.

Viewed more positively the emphasis on science and engineering might have been an indication that science and engineering courses were becoming more inclusive of environmental concerns; from the courses' definitions of environment and their stated philosophies, however, indications were that most tertiary environmental courses were using the terminology of O'Riordan (1981) still more technocentric than socially critical.

The distinctions between courses were not always clear. There was a not surprising similarity between environmental science and engineering courses, and also between
environmental studies and education courses. This was particularly evident from the definitions of the 'environment' used in the various courses; refer to Table 3.4. The stated philosophies of all four categories of courses were very similar; refer to Table 3.5. Either there was a consistency of philosophy across the courses or the language used was such that general differences in practice were hidden.

However differences in practice emerged when teaching approaches were considered; refer to Table 3.6 teaching and assessment. Across the range of courses there was a reliance on group work and projects or field work, but there were indications that the environmental science and engineering courses relied more on lectures and tutorials/practical sessions in their teaching methods. Environmental studies and education courses used a wider variety of teaching approaches, and explorative and interactive learning opportunities were fostered.

A fundamental characteristic of socially critical environmental education is the involvement of a range of disciplines (Thomas 1993), preferably presented in situations which assist students to integrate inter-disciplinary or trans-disciplinary experiences. In its report on British environmental education the Committee on Environmental Education in Further and Higher Education (1993) noted that most environmental science, environmental engineering and environmental studies courses referred to themselves as inter-disciplinary although many were thought to exhibit more multi-disciplinary characteristics. A number of courses in this study which claimed to be single disciplinary, as shown in Table 3.3, also described themselves as environmental. A large number of courses described themselves as multi-disciplinary or cross-disciplinary rather than interdisciplinary or integrative. Some, while describing themselves as interdisciplinary seemed to offer little material on interdisciplinary problem solving or integrative approaches.

Many courses used the term 'environment' in their title or for their promotion and had a focus on environmental concerns, yet appeared not to exhibit the interdisciplinary approaches nor the social analyses that might logically be expected. The indications were that some courses although 'environmental' in name may have exhibited little of the content and understanding which would give students the experience of an interdisciplinary environmental education. If we take Fensham's (1987) description of environmental education as being education about the environment, in the environment and for the environment, that is seeking ways to bring about improvements, then some of the courses in this survey should probably not be regarded as offering environmental education.
It appeared that environmental courses were generally producing graduates capable of meeting the demands of Australian employers. Brown and Clarke (1996) found that graduates from interdisciplinary environmental courses had been sought after by employers. Analytical capacity, communication skills, problem solving and group work skills were among the main competencies indicated by business people as important (Marginson 1993). The list of graduate competencies set out in Table 3.7 shows there were some differences of emphasis across the four course categories, but it is difficult to discern specific trends. The environmental education courses however indicated broader socially orientated competencies compared to those of the other courses which tended to be more skills focused. Overall across the categories of courses there was a close match between Marginson's findings and the perceived competencies of graduates. This match suggests that staff of environmental courses can promote them confident that experiences offered by the courses will assist graduates to gain employment.

It is probable that employers were not fully aware of the difference between courses and particularly of the character of environmental studies courses. In this regard the findings of the Committee on Environmental Education in Further and Higher Education in Britain (1993) may also apply in Australia:

Broadly based degree courses in Environmental Science, Environmental Engineering and Environmental Studies have a potentially important part to play in the development of an environmentally responsible workforce. In many cases, however, there is a need for a careful reappraisal of course content and objectives in the light of employment opportunities actually available. There is also a need to ensure that graduates' capabilities are more widely understood by employers, particularly in industry.

Comments about factors which helped graduates to gain employment are shown in Table 3.7. It appeared that staff were already aware of the benefits of informing potential employers of the abilities of their graduates. It is indicated that networking and exposing employers to students' work assisted students. Respondents in the early study by (Thomas 1993) gave these ideas considerably more attention than matters related to specific course content or academic standard which might also have given graduates of a particular course a 'market advantage'.

There is presently a need for tertiary environmental educators to have a clear understanding of the employment market. This is particularly important since 'environmental positions' can be poorly defined. The work by Brown and Clark (1996) indicated that employers, rather than defining an 'environmental graduate' narrowly,
were tending to keep their options open by making the degree specifications broad and indicating in duty statements the environmental area or background they were seeking. Building on insights such as this a deeper understanding of employment opportunities and of the market may come through the development of additional links with 'outside' organisations and through working closely with professional associations such as the Environmental Institute of Australia and the Institution of Engineers Australia with their attention to accreditation of courses.

This picture of diversity in environmental studies in Australia is similar to that found by Bahnmuller et al. (1992) in USA where environmental studies on campuses had "...grown in fits and starts...but academia [had] not yet offered an unconditional welcome to this still-maturing subject". More particularly, she estimated that only some 10% of institutions offer environmental studies as a major and concluded with the observation that:

If environmental studies is to be an enduring academic tradition...academia may have to relay its foundations. It will have to value an integrative approach to learning and support that approach with the rewards it currently reserves for its specialists'.

These observations and the data presented in indicate that tertiary environmental educators need to be involved in more sustainable discussion about the character and direction of their courses. Greater cooperation in and coordination of efforts to provide diversity and interest in course offerings would help avoid duplication. It is critical to the employment of graduates that clear understandings of the foundations of environmental education and of the different emphases of the various courses be developed, particularly amongst employers. Further, if environmental education is to become an established part of all tertiary academic curricula, then environmental educators need to coordinate their efforts so that the value of different kinds of environmental courses can be clearly articulated and promoted.

In the past loose networks have been developed with the intention of promoting cooperation. The Environment Institute of Australia and the Institution of Engineers Australia have discussed the issues associated with the accreditation of environmental courses. However these efforts have been inconsistent particularly in regard to the role of postgraduate courses.

A catalyst for discussion of these matters would be a broad review of the status and direction of environmental education in Australian tertiary institutions similar to the Toyne
report undertaken in Britain (Committee on Environmental Education in Further and Higher Education 1993). Such a review would necessitate a consideration of what the hallmarks of environmental education are. As occurred in Britain the review could lead to proposals for the development of a policy for environmental or green curricula in Australian tertiary institutions. This was hinted at in the National Strategy for Ecologically Sustainable Development (Commonwealth of Australia 1992), but there has been little evidence of subsequent interest by the government or its agencies.

Such a review would provide opportunities for environmental course educators to assess how their courses related to one another and to the more traditional disciplinary courses. Discussion of the merits of such a review and development of a broad environmental education policy may both be generated if we press our professional associations and institutions to generate support for the proposal. Environmental course educators have a reputation for being politically active when it comes to the future of their courses; it seems that the time has come for us to become active again.

3.4 Environmental Education for Engineers

A survey of engineering education establishments in Australia was undertaken by the Engineering Panel of the Sydney Division of the Australian Institute of Engineers by Bandler (1989). It indicated that whilst environmental matters were receiving more attention in contemporary courses, there was a lack of coherent focus in relating these matters to mainstream engineering concerns. Some institutions offered environmental course elements at undergraduate level, whilst others restricted them to postgraduate studies. The courses were usually optional, and it appears that a significant number of students in Australia could complete studies with no formal association with environmental subjects. This is believed to be a serious deficiency in current curriculum arrangements.

3.4.1 The Need for Environmental Courses

Clause 1 of the Code of Ethics of the Institution of Engineers of Australia, states that:

"The responsibility of Engineers for the welfare, health and safety of the community shall at all times come before their responsibility to the Profession, to sectional or private interests, or to other Engineers."

In fulfilling such an obligation, engineers have a duty to consider the effects of their works on the total environment of the community. Environment in this sense should be
understood as including all aspects of the surroundings of man, whether affecting him as an individual or in his social groupings.

Engineers are traditionally taught to solve specific problems such as the size of beams for a structure, the capacity of a road to cope with traffic, or the size of a motor to pump water at any given rate. The underlying approach to engineering problems tends to be to seek economical solutions to overcome technical problems. Where there are no analytical formulae based on accurate theories, engineering students are encouraged to make simplifying assumptions. They will also tend to design or plan their schemes to have simple geometric forms, so that they become easier to set out and/or calculate. When confronted with an environmental problem which threatens to hinder or complicate the execution of their plans, they may either fail to perceive its existence, or resent it as an impediment to progress.

On a more general level, traditional engineering courses are believed to be deficient in preparing the profession to become involved in questions of community costs and benefits. Ironically, engineers have the earliest awareness of many proposals. Their decisions are usually regarded as first order requirements of a project. If these requirements are applied in an inflexible way, they can constrain all subsequent decisions. Engineers have an opportunity, and a responsibility, to play a leading role in encouraging public discussion and contributing adequate professional assessments of likely impacts. Engineering education must equip engineers to satisfy this need.

3.4.2 Nature of The Courses

Although it should be a long term aim of the academics to integrate environmental considerations into engineering units, this will not happen in the short to medium term. The depth of environmental concerns in an engineering course will vary with the lecturer, so that while some subjects will have a good coverage of relevant environmental issues, others will, at best, present only a narrow perspective of such problems e.g. the technical solutions, but not the social and economic ones. It is argued that a specific environmental course appears to be the only immediate way to achieve appropriate environmental goals.

The question has also been raised whether such training should be at undergraduate or postgraduate level. Environmental training is best undertaken at the undergraduate level since it is the only forum which will reach all engineers. Furthermore, the environmental component of engineering should be an integral part of engineering practice. Hence environmental training at the earliest practicable stage should help promote the automatic inclusion of environmental factors at the initial stages of planning for engineering works.
3.5 State of Environmental Engineering Education

Cortese (1992, p. 93) notes that:

"... the current education of most environmental professionals is incomplete. Most are trained to deal with a subset of environmental problems, such as air pollution, water pollution, or hazardous waste, but not with environmental issues in an integrated, comprehensive fashion."

Most technical courses stress "end-of-pipe" treatment (Soloviev, 1992), albeit that it is done to reduce pollution or to more efficiently treat waste. Until recently, few curricula covered waste minimisation or the prevention of pollution through a redesign of the manufacturing process; in other words, cleaner production. A survey by USEPA's National Advisory Council on Environmental Policy and Technology indicated that major pollution prevention courses were taught in only 10 to 15 of the country's almost 400 engineering schools (Allen, 1992).

Cortese (1992) noted that one possible reason for this situation is the traditional single discipline nature of most university departments. This does not allow environmental expertise to be easily used across departmental or faculty barriers unless individual academics have a particular interest in doing so. As Page (1992) notes, it is necessary to have an "environmental champion" in the university to help catalyse action. In addition, multidisciplinary curricula are often considered soft and academically less rigorous than traditional single discipline curricula. This aspect is noted by Cortese (1992) in relation to environmental courses.

However, it is essential to stop this way of thinking, as environmental problems are by their nature multidisciplinary and it is, therefore, necessary to develop multidisciplinary environmental education curricula and multidisciplinary research projects to underpin the solutions. The development of strategies for the prevention and/or solution of environmental problems will involve physical, natural and social science disciplines, and these need to be reflected in the curriculum. The task is to design and develop curricula that contain an appropriate and acceptable mixture of multidisciplinary and single discipline skills in order that the graduate can not only discuss the broader issues, but actually contribute to the design and management aspects in their chosen field. It is essential to develop sufficient skills to produce the hard results in industry and the public service.
In relation to environmental engineering education, Page (1992) provides five basic questions to be addressed. These relate to the interdisciplinary nature of environmental education, how best to achieve it and how it can be most effectively focused towards achieving cost effective, ecologically sustainable, technical solutions.

A number of reasons exist by Page (1992) for the slow progress on environmental education. These include:

- a lack of a sense of urgency because awareness of the importance of the subject is not widespread;
- economic recessions make inclusion of environmental education requiring more resources difficult to achieve;
- a lack of cooperation between industry and academia; and
- faculty resistance to change for reasons such as innate conservatism, lack of time, unavailability of suitable teaching materials, curriculum crowding etc.

3.5.1 Course Objectives

It is suggested by (Bandler, 1989) that a suitable course should satisfy the following objectives:

1. To foster a view that environmental sensitivity is an integral part of all good engineering. Environmental considerations are not something of peripheral concern, but are central to the competent design, construction and operation of engineering works. Environmental values should not be optional extras clipped onto a project at great cost after it is fully designed, but must be a fundamental element in project evolution. The objective implies a requirement for knowledge of environmental issues and legislation. It is essential that undergraduate engineers be made aware of potential environmental implications of engineering works. There is a need to engender environmental sensitivity at an early stage in the education process. Good engineering is inseparable from an awareness of sound environmental principles.

2. To achieve a basic understanding of environmental principles. This objective implies an appreciation of the differences between renewable and nonrenewable resources. Engineering undergraduates should be made aware of interrelationships between different components of the natural and man-made environment. It is probably best achieved by a systems approach to environmental education.

3. To broaden the horizons of engineering undergraduates. It would be desirable to expose engineering students to professional disciplines in the social and natural sciences that they would not encounter elsewhere in their courses. Although this contact would
necessarily be relatively superficial, it must be made meaningful. It would also be of benefit to allow students to interact with contemporaries from other faculties having different professional backgrounds, training and values.

4. To enhance the group interaction and communication skills of engineering undergraduates. Engineers often have a problem communicating with professionals from the natural and social sciences. This can lead to misunderstanding and conflict when many words are spoken but no transfer of information takes place. A core environmental course could give a unique opportunity to bring together undergraduates from a variety of faculties for group projects. Such a course segment would provide students with a realistic example of the achievement of group results from a number of individuals whom they did not pick, with expertise with which they were unfamiliar in an overall timetable which they did not set. This will forcibly bring forward the value of group dynamics, communication skills, project organisation and the need to appreciate the perspective of others.

5. To provide an appreciation of the importance of values in engineering decision making. Some engineers tend to approach their professional task with little appreciation of the importance of non-technical factors. Attitudes to man-nature relations, for example, are dynamic and affected by a host of cultural and social determinants. Engineering works are carried out in a context of political and economic relationships whose relevance should be recognised.

3.5.2 Environmental Engineering Degrees

Graduates from environmental engineering degrees should have the ability to address environmental problems and to focus on practical solutions in a way that is currently difficult because of the single discipline nature of most existing engineering curricula. There is a need to develop an engineer with a sound background in the physical sciences who also has a broad understanding of environmental, social and political processes and issues. The students must be exposed to a range of perspectives on environmental management and be able to communicate effectively with specialists from other disciplines, management, employees, individual citizens and community organisations. In other words, they need to embrace sustainability as a primary goal, thereby turning to face the sun. A graduate in environmental engineering should have the background to:

- understand the processes of natural and urban environmental degradation, its causes and possible solutions;
- understand the working environment, the health aspects and the relationship to the external environment;
- understand global environmental changes;
• assess the environmental impacts and effects of the processes of modern technology, industry, land development and aquatic development;
• incorporate environmental criteria in all stages of design, development and implementation;
• develop effective environmental and resource management systems;
• understand the development of environmental policy and its implementation; and
• understand the political, social and economic factors in environmental management.

However, it will not be possible for an environmental engineering graduate to cover all these topics in depth. A suitable environmental engineering curriculum should have a sound basis of mathematics and sciences, including ecology and biology. The curricula should contain a basic core of engineering synthesis and design, taught in a broader context than is currently achieved in single discipline curricula, enabling the engineer to consider very different solutions to existing problems. In addition, a sound base in economics is required, together with environmental law, communication, ethics, social science and management skills. Luthy et al. (1992) note that risk analysis and risk assessment also need to be included. They note that it is no longer sufficient to simply study fluid mechanics and chemistry as if all environmental problems were water based. The total package must have an overriding philosophy for achieving sustainable development, as indicated throughout Agenda 21.

Codner et al (1993) outline some of the environmental engineering education initiatives that are taking place. Within Australia, there are approximately 18 environmental engineering undergraduate degrees existing or in the planning stage. The oldest course produced its first graduates in 1992. Most of the courses have been developed from either existing civil engineering or chemical engineering courses, with additional units added to provide a broader base. Because of the way in which the courses have developed, there is sometimes not an overriding philosophy of the achievement of sustainable development, and much of the technology taught still relates to “end-of-pipe” waste treatment rather than cleaner production or pollution prevention.

The environmental engineering courses have the opportunity to produce an environmentally competent engineer with a different attitude to the environment and problem solving compared to engineers educated within single discipline courses, either now or in the past. This reflects the new technical culture referred to by Thom (1994).

If the emerging environmental engineering courses do not provide a graduate sufficiently differentiated from the single discipline product, then the marketplace is likely to react
accordingly and the opportunity to achieve a paradigm shift in engineering practice will have been missed. This must not be allowed to happen and academics have a responsibility to make sure the new graduates meet market demands or, better still, shape them.

3.5.3 Single discipline Engineering Degrees

The development of undergraduate environmental engineering courses is partly market driven, but also partly an admission of failure in the environmental education within engineering degrees. This situation has largely occurred because it is difficult to alter existing single discipline course to make them environmentally aware. It has been much easier to develop new “marketable” courses clearly labelled as environmental engineering. The question is sometimes asked, does this mean that other engineering courses are not environmental? The answer is often yes, as shown by Codner (1993). There will probably always be many more engineers graduating from single discipline courses than from environmental engineering courses. Therefore, if we are to change attitudes of new graduates and really move towards sustainability, it is imperative that environmental issues are integrated into single discipline engineering courses, such as chemical engineering, civil engineering, etc. Within these courses, environmental issues should be integrated into existing course modules, as well as being taught in specialised environmental subjects.

The European Society for Engineering Education (SEFI), which comprises about 250 institutions of higher education, established a working group on environmental engineering in 1991. One of their objectives was the formation of a strong group from universities and industry to raise awareness and stimulate activities in the area of environmental engineering. One of the working group’s first activities was to hold a seminar on “Environmental Engineering-A Challenge for Europe” (Bahnmuller et al, 1992). A major theme of the seminar was the introduction of environmental education into engineering courses and the reasons why this was necessary.

Duffell (1993) notes the need for the “greening” of engineering curriculum. He provides an example of a course model on planning and environmental technology developed for civil engineering students. Duffell (1993) also notes the actions of the Institution of Chemical Engineers (UK) in providing environmental guidance to academic institutions seeking degree accreditation illustrated in Table 3.8. They developed a matrix under three headings-awareness, understanding and in-depth knowledge-through either incorporation in existing studies or enhancement through specific topics.
A study of civil, chemical, mechanical and manufacturing engineering courses at eight
Australian universities has shown that they include only a small amount of environmental
ing工程 and technology (Codner, 1993). The chemical, mechanical and
manufacturing courses have almost no direct environmental input, although the basic
technology is often taught.

The range of environmental engineering subjects in the civil engineering courses studied
is from 0% to 17% (Table 3.9). In some courses, it is possible to bypass environmental
subjects altogether. Most of the environmental subjects relate to hydrology and water

Table 3.8. Environmental protection education working party matrix (IChemE, 1992)

<table>
<thead>
<tr>
<th>Awareness</th>
<th>Incorporated in existing studies (using or indicating environmental examples)</th>
<th>Enhancement through specific topics (introducing optional or mandatory topics)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Awareness</td>
<td>• Basic chemical engineering • Legislative procedures • Engineers in society, (interaction with other issues, environmental impact)</td>
<td>• Historical review • Legislation • Impact of products (cradle to grave analysis) • Nuisance • Renewable/non-renewable resources • Risk acceptability</td>
</tr>
<tr>
<td>Understanding</td>
<td>• Basic chemical engineering • Bio sciences • Particle technology • Computing (environmental modelling) • Economics • Design studies (integrated pollution control)</td>
<td>• Geographical (global, local physical and social) • Prevention and control techniques (Assessment techniques, eg environmental audits) • Treatment techniques (eg gas, liquids, solids) and case studies (eg nuclear, pharmaceutical, combustion) (Cleaner technology)</td>
</tr>
<tr>
<td>In-depth knowledge</td>
<td>• Basic chemical engineering (via design project and other projects)</td>
<td></td>
</tr>
</tbody>
</table>
Table 3.9. Breakdown of civil engineering courses in Universities by subject areas (Calendars of 1998)

<table>
<thead>
<tr>
<th>Subject area</th>
<th>Percentage of the course</th>
<th>Melb</th>
<th>Monash</th>
<th>RMIT</th>
<th>UNSW</th>
<th>UTS</th>
<th>Adelaide</th>
<th>UWA</th>
<th>Curtin</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>A</td>
<td>E</td>
<td>P</td>
<td>C</td>
<td>S</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Math/Science</td>
<td></td>
<td>21</td>
<td>19</td>
<td>13</td>
<td>13</td>
<td>22</td>
<td>19</td>
<td>19</td>
<td>25</td>
</tr>
<tr>
<td>Traditional Engineering</td>
<td></td>
<td>65</td>
<td>59(^2)</td>
<td>65</td>
<td>6</td>
<td>56</td>
<td>57</td>
<td>6</td>
<td>54</td>
</tr>
<tr>
<td></td>
<td></td>
<td>70</td>
<td>8</td>
<td>62</td>
<td>8</td>
<td>8</td>
<td>69</td>
<td>82</td>
<td>76</td>
</tr>
<tr>
<td>Environmental Eng &amp; Tech.</td>
<td></td>
<td>5</td>
<td>5</td>
<td>9</td>
<td>2</td>
<td>8</td>
<td>9</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15</td>
<td>14</td>
<td>14</td>
<td>4</td>
<td>4</td>
<td>17</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>Inter-disciplinary</td>
<td></td>
<td>9</td>
<td>7</td>
<td>14</td>
<td>20</td>
<td>4</td>
<td>8</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>Electives</td>
<td></td>
<td>5</td>
<td>23(^3)</td>
<td>4</td>
<td>4</td>
<td>6</td>
<td>3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: 1998 University and Faculty calendars

A: Asset Management Stream
E: Environmental Management Stream
P: Project Management Stream
C: Civil Stream
S: Structural Stream

1. Subject areas have been broadly define as:
   - Math/Science: includes maths, physics, chemistry, geology;
   - Traditional Engineering: subjects which may be necessary for solving environmental problems, but which are not taught in environmental context, e.g. hydraulics or chemical process engineering;
   - Environmental Engineering & Technology: engineering and science subjects that involve direct environmental topics; e.g. public health engineering, transport planning, environmental impact assessment;
   - Interdisciplinary: usually management, economics, communications, or engineering and society;
   - Electives: free choice of subjects. Choice not usually indicated.

2. Top figure represents the minimum percentage, and the bottom figure the maximum percentage.
3. Electives have been distributed between traditional and environmental engineering subject areas.
The review of chemical engineering courses is shown in Table 3.10. The major point to note is the almost total lack of environmental subjects. Traditional engineering subjects account for at least two thirds of the course. Although many of the courses are concerned with topics related to environmental problems, for example, process engineering, process design, reaction engineering, transport phenomena etc., they do not appear to be applied to environmental problems in a way that the students would recognise. This problem was also noted in electrical engineering at the University of Sydney by Choi and Pudlowski, (1992). Some of this may be overcome in design subjects but, again, this is not obvious. It is necessary to relate subjects like reaction and process engineering to environmental problems within the context of sustainable development. It may be possible to take some of the electives in environmental areas; however, in most cases it appears more likely that they will be in traditional engineering subjects. The concepts of waste prevention and cleaner production receive very little mention. The emphasis is still on efficient “end-of-pipe” treatment.

Table 3.10. Breakdown of chemical engineering courses in Universities by subject areas (Calendars of 1998)

<table>
<thead>
<tr>
<th>Subject area</th>
<th>Percentage of the course</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Melbourne</td>
</tr>
<tr>
<td>Math/Science</td>
<td>32</td>
</tr>
<tr>
<td>Traditional Engineering</td>
<td>67</td>
</tr>
<tr>
<td>Environmental Eng &amp; Tech.</td>
<td>1</td>
</tr>
<tr>
<td>Inter-disciplinary</td>
<td>3</td>
</tr>
<tr>
<td>Electives</td>
<td>11</td>
</tr>
</tbody>
</table>

Source: 1998 University and Faculty calendars

1. Elective have been distributed between traditional and environmental engineering subject areas.

The review of mechanical and manufacturing engineering courses is shown in Table 3.20. The range of traditional engineering courses is from 50% to 82%, which is much broader than for either civil or chemical engineering. However, the range does not translate into a larger share of environmental subjects, but into more mathematics and science, and interdisciplinary subjects, which usually relate to accounting and management. The maximum possible environmental content is 6%, with most courses including no subjects that relate directly to the environment. The environmental subjects
covered relate to air pollution, environmental noise and energy concepts. The manufacturing courses do not appear to relate to cleaner production, resource management and energy concerns.

Table 3.11. Breakdown of mechanical and manufacturing engineering courses in Universities by subject areas (Calendars of 1998)

<table>
<thead>
<tr>
<th>Subject area</th>
<th>Percentage of the course</th>
<th>Melbourne</th>
<th>Monash</th>
<th>RMIT</th>
<th>UNSW</th>
<th>UTS</th>
<th>Adelai</th>
<th>UWA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mech</td>
<td>Man</td>
<td>Mech</td>
<td>Mech</td>
<td>Man</td>
<td>Man</td>
<td>Mech</td>
</tr>
<tr>
<td>Math/Science</td>
<td>21</td>
<td>21</td>
<td>19</td>
<td>17</td>
<td>11</td>
<td>28</td>
<td>28</td>
<td>15</td>
</tr>
<tr>
<td>Traditional Engineering</td>
<td>69</td>
<td>70</td>
<td>70</td>
<td>68</td>
<td>74</td>
<td>50</td>
<td>55</td>
<td>71</td>
</tr>
<tr>
<td>Environmental Eng &amp; Tech.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inter-disciplinary</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>11</td>
<td>13</td>
<td>6</td>
<td>11</td>
<td>7</td>
</tr>
<tr>
<td>Electives</td>
<td>5</td>
<td>5</td>
<td>18</td>
<td>4</td>
<td>15</td>
<td>5</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

Source: 1998 University and Faculty calendars

1. Elective have been distributed between traditional and environmental engineering subject areas.

The new concepts of sustainable development, waste prevention and minimisation, life cycle analysis and cleaner production do not appear to have found their way into curricula as yet. Although it is appreciated that some of these ideas are relatively new, it is felt that more action should be taking place to include them in curricula.

Economics related to the environment, rather than simply project management, needs far more attention. This requires consideration of environmental degradation as an economic cost of a project, rather than either an externality, or worse still being ignored and resulting in a cost to the community at some later stage. Sustainability demands inclusion of this topic in subject curricula.

Varcoe (1991) has also recognised the need for all engineers to have some environmental education and has devised a single subject called "Engineer and the Environment" for this purpose. In summary, the subject covers:

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Chapter 3: Resources Survey
• the earth as a system;
• engineering life cycles—waste avoidance;
• engineering to solve environmental problems;
• environmental problems;
• environmental law;
• the green scene;
• the role of the media; and
• the role of engineering in ecologically sustainable development.

The University of Sydney has recognised the need for environmental education for electrical engineers and has developed a one semester subject on environmental issues relating to energy, power generation, electricity distribution, electromagnetic radiation and remote sensing (Choi and Pudlowski, 1992).

Accrediting bodies need to follow the lead of the Institution of Chemical Engineers (UK) and develop guidelines for the inclusion of environmental concepts into existing engineering courses.

3.6 Summary

Sustainability is the way of the future. Our vision should be that by the year 2005-2010, all engineers should adopt and implement the concepts of sustainability as a normal part of their professional activities.

To achieve this vision, a paradigm shift is required on the part of engineer education. It is essential to achieve a shift from unsustainable development to sustainable use of the Earth’s resources, which will require the linking of development with protection of the environment. The basis for this paradigm shift must be an “attitudinal and behavioural change” by engineers. Change must occur at all levels within the profession, that is, in professional organisations, practising engineers, educators and students. Attitudinal change must be the focus of current activities, for without it the move towards sustainability will not occur.

The vision will not be achieved without considerable effort from professional organisations, education institutions, companies and individuals. The problem is too complex to expect individuals to be able to embrace sustainability and implement the concepts within their own work environment. Professional organisations through their accreditation process need to provide a leadership role for the profession in achieving the above vision and moving towards sustainability.
Education is considered the key in moving towards sustainability. This will require actions at various levels, such as undergraduate education through environmental engineering degrees and the incorporation of environmental engineering areas and continuing education for practising engineers. The latter will also involve modules ranging from awareness raising courses to detailed courses on the implementation of sustainability concepts to specific engineering sectors.

It is recommended that higher education institutions become signatories to the Talloires Declaration. This will help define the corporate environmental philosophy and provide a suitable framework for environmental education and research. It should also allow easier development of environmental initiatives from departments and faculties. "Train the trainer" sessions on environmental awareness raising and environmental education should also be considered.

Professional engineering organisations also need to provide input into environmental education. This may be through guidelines for environmental engineering courses and the inclusion of environment content into single discipline courses. All of this must be focused to achieve attitudinal and behavioural change, after which the move towards sustainability will become easier.

It is the responsibility of all engineers to understand and accept the need for sustainability and, hence, the practice of engineering that leads to sustainability.
Chapter Four

Research Methodology

4.1 Introduction

The research had three methodological components: an extensive literature survey, a questionnaire addressing the issue environmental education of engineers circulated to the engineering staff in all Australian universities, and a more detailed profile to address environmental education of engineers written by a senior engineering academic.

The literature survey chapter 2 presented previously summarised and analysed existing research on the issue of environmental education in tertiary education and the professions, and more generally the environmental education of engineers. The literature look into account the growing volume of internet resources available in the fields of environmental education, both for engineers and for environmental education more generally.

The questionnaire in chapter 5 administrated to academic staff addressed issues relating to environmental sustainable development, then focused on the specifics of environmental education of engineers. The final section of the questionnaire addressed the issues of barriers to the development of environmental education of engineers, and examined possible syllabus change and proposed objectives that might be conducted.

The profile in chapter 5 covered the same kinds of issues addressed in the questionnaire, but gave a more in depth understanding of the situation in Australia, from the perspective of an "on-the-ground" expert or practitioner. The profile has been developed to raise a number of issues relating to the overall direction and structure of environmental engineering courses. It is not prescriptive, and gives some guidance as to what is considered necessary within environmental engineering courses.

This chapter begins with an introduction which provides a link to a summary of the research questions, respondents and data sources which is followed by an overview of the data analysis by research issues and sub-issues.

4.2 Survey

Four 'elements' of the curriculum area are considered-empirical, synoptic, aesthetic and ethical. These have been referred to and expressed in slightly different ways in a number
of curriculum statements, which states that a program of environmental education should disseminate the views of Project Environment:

It contains empirical, synoptic, aesthetic and ethical elements, none of which can be studied in isolation:

- **The Empirical element:** This is concerned with those aspects of the environment which lend themselves to objective observation, measurement and analysis. The main priority to ensure that all students have as many opportunities as possible of making direct contact with the environment through observation and by measuring, recording, interpreting and discussing what has been observed.

- **The Synoptic element:** Students need to be made aware of the complex nature of the environment. The aim of synoptic studies is to help students to realise the complexity of such issues and to introduce them to the inseparable nature of the various components of an environment and to the interrelations of these. Method is as important as content in achieving this.

- **The Aesthetic element:** Of the many aspects of the environment, perhaps the most important are qualitative rather than quantitative. The aesthetic elements can help a student to realise that there is no right or wrong answer in absolute terms to aesthetic questions and that the answer to environmental issues is frequently a compromise.

- **The Ethical element:** A program of environmental education aims at introducing students to the idea of personal responsibility for the environment and to the concept of stewardship. It trains students to ask if the criteria of proposed actions are based on morally justifiable values.

**4.2.1 The three dimensions of learning**

Inextricably interwoven with these various elements are the three dimensions of the learning process: knowledge and understanding, skills and attitudes. Once again, these are referred to and articulated in a variety of documents which attempt to define the aims and content of environmental education. For example:

**4.2.1.1 Knowledge and skills**

- To develop a coherent body of knowledge about the environment, both built and rural, sufficient to recognise actual and potential problems,
• To be able to gather information from or about the environment independently or as part of co-operative activity,

• To be able to consider different opinions related to environmental issues and to arrive at a balanced judgment,

• To appreciate the ways in which environmental issues are inter-related so that one factor affects others,

• To be able to evaluate information about the environment from different sources and to try to resolve environmental problems,

• To understand and to know how to use the mechanisms available in society for bringing about environmental change.

4.2.1.2 Attitudes and behaviour

• To develop an appreciation of the environment and critical awareness of the natural and built environment,

• To develop an attitude of concern for environmental matters and a wish to improve environmental understanding,

• To be critical of one's own environmental attitudes and to take steps to change one's own behaviour and actions,

• To have a desire to participate in initiatives to care for or improve the environment,

• To wish to participate in environmental decision making and to make opinions known publicly.

The survey questionnaire was designed to gather information on the status and direction of environmental education of engineers in Australia. The goal of this survey is to assess the level and kind of environmental education engineers are being offered in Australia, and to identify the key issues and problems facing staff who teach these courses. These goals and principles have been carried forward into and underpin the content of the survey for environmental education of engineers in Australia. The key areas of interest identified in the questionnaire included:

• The key environmental issues to be covered in engineering degrees,

• The essential environmental knowledge does an engineer need,

• The environmental attitudes, and skills are needed by engineers,

• The key topics to be developed in engineering degrees,

• The key goals to be developed in engineering degrees,

• The factors influencing the demand for graduates,

• Syllabus or courses review,
The objectives to be covered within an engineering degrees,
The communication skills to be developed throughout engineering degrees,
The level of importance to be given to sustainability ethics.

The results of the questionnaire provided base-line data for use in the mapping of the environmental education of engineers in Australia. Items will be subsequently used in the identification of possible strategies to further develop the environmental education of engineers.

It should be noted that the questionnaire was not designed to give a comprehensive and exact measurement of the status of the environmental education of engineers in Australia. The questionnaire only gave an approximate picture of the situation in Australia. Further, some of the questions rely on the informed opinions of the respondents rather than on fact and so must be considered subjective. What the questionnaire results do provide is a "snap-shot" of the situation in each responding university according to informed experts.

The questionnaire was circulated to appropriate respondents in each school or department in all Australian universities. They were asked to identify at least two respondents from each school or department in order to maximise the chances of receiving responses. The results were condensed into a single national response.

4.2.2 Development of questionnaire

Figure 4.1 presents an overview of the composition of the questionnaire employed by the researcher to collect data for this study. Across the top are the headings of each column with the overview of the composition of the questionnaires. The headings were the ten sections of the questionnaire, each of the ten sections consisted of general components related to the headings. A rating scale 1 to 4, where 1=most important, 2=quite important, 3=some importance, 4=not important was used.

The content of the questionnaire in Figure 4.1 and Appendix I were developed from the findings of the literature review and the researcher's personal knowledge of the engineering schools in Australia. The questionnaire was trialed with three staff from University of Wollongong. The staff completed their questionnaire through an interview with the researcher whose task was to ensure that they understood the questions and their responses were correctly recorded. Adjustments to the questionnaire were made before they were finally printed.
<table>
<thead>
<tr>
<th>Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engineering for sustainable development</td>
</tr>
<tr>
<td>The ethics implicit in environmental engineering</td>
</tr>
<tr>
<td>The philosophical basis of public concern for the environment</td>
</tr>
<tr>
<td>The basic principles of environmental science</td>
</tr>
<tr>
<td>The different opinions of scientists, engineers, and the public on environmental issues</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Knowledge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge of the environmental setting of an engineering problem</td>
</tr>
<tr>
<td>Knowledge of monitoring procedures and assessment standards of environmental quality</td>
</tr>
<tr>
<td>Knowledge of relevant environmental legislation and policy</td>
</tr>
<tr>
<td>Knowledge of environmental design and cleaner production</td>
</tr>
<tr>
<td>Knowledge of environmental economic management for sustainability</td>
</tr>
<tr>
<td>Knowledge of environmental risk assessment and knowledge of occupational health and safety</td>
</tr>
<tr>
<td>Knowledge of environmental precautionary principles</td>
</tr>
<tr>
<td>Knowledge of environmental life cycle analysis</td>
</tr>
<tr>
<td>Knowledge of environmental management procedures</td>
</tr>
<tr>
<td>Knowledge of the role of the engineer in the society</td>
</tr>
<tr>
<td>Knowledge of the impact of engineering technology on social structure and culture</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Attitudes &amp; skills</th>
</tr>
</thead>
<tbody>
<tr>
<td>A commitment to environmental sustainability</td>
</tr>
<tr>
<td>A commitment to global responsibility</td>
</tr>
<tr>
<td>An appreciation of the complexity of the biosphere</td>
</tr>
<tr>
<td>An appreciation of uncertainty, complexity and change</td>
</tr>
<tr>
<td>The development of a systems approach to design and management</td>
</tr>
<tr>
<td>The development of skills in quantitative and qualitative assessment</td>
</tr>
<tr>
<td>The development of skills needed to deal with complexity</td>
</tr>
<tr>
<td>The development of skills needed to take a long term view of projects</td>
</tr>
<tr>
<td>The development of skills needed to apply criteria against which to assess proposals</td>
</tr>
<tr>
<td>The development of skills needed to apply the guiding principles from ethical practice</td>
</tr>
<tr>
<td>The development of skills needed to relate and understand environmental issues, beyond an engineer's immediate specialisation</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Topics</th>
</tr>
</thead>
<tbody>
<tr>
<td>System approaches to environmental problems</td>
</tr>
<tr>
<td>Problem solving approaches</td>
</tr>
<tr>
<td>Government environmental policy and legislation</td>
</tr>
<tr>
<td>Communication with other professionals</td>
</tr>
<tr>
<td>Local, regional and global environmental problems</td>
</tr>
<tr>
<td>Environmental economics</td>
</tr>
<tr>
<td>Ecological understanding</td>
</tr>
<tr>
<td>Appreciation of a range of different value systems in understanding environmental issues, social issues and policy</td>
</tr>
<tr>
<td>Environmental law and policy issues</td>
</tr>
<tr>
<td>Sustainable development concepts</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Goals</th>
</tr>
</thead>
<tbody>
<tr>
<td>To produce engineers (IEAust Category 2-4)</td>
</tr>
<tr>
<td>To underpin engineering knowledge (IEAust Category 1)</td>
</tr>
<tr>
<td>To develop breadth of issues (IEAust Category 2)</td>
</tr>
<tr>
<td>To integrate concepts (IEAust Category 3)</td>
</tr>
<tr>
<td>To develop professional responsibility (IEAust Category 4)</td>
</tr>
<tr>
<td>To develop management skills (IEAust Category 5)</td>
</tr>
<tr>
<td>To develop policy (IEAust Category 5)</td>
</tr>
<tr>
<td>To develop communication skills (IEAust Category 4)</td>
</tr>
<tr>
<td>To enhance communication skills (IEAust Category 4)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of government policy</td>
</tr>
<tr>
<td>Lack of political commitment to environmental education of engineers</td>
</tr>
<tr>
<td>Lack of school or department response to policy</td>
</tr>
<tr>
<td>Lack of understanding of environment issues in engineering disciplines</td>
</tr>
<tr>
<td>Lack of qualified lecturers/teachers</td>
</tr>
<tr>
<td>Lack of funds to employ lecturers/teachers</td>
</tr>
<tr>
<td>Lack of funds to develop teaching materials</td>
</tr>
<tr>
<td>Resistance in engineering disciplines to environmental education</td>
</tr>
<tr>
<td>Disciplinary/faculty barriers to cooperation with other environmental educators</td>
</tr>
<tr>
<td>Lack of room in curriculum</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Syllabus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objectives</td>
</tr>
<tr>
<td>Develop core engineering skills</td>
</tr>
<tr>
<td>Develop a satisfactory scientific base for understanding environmental issues</td>
</tr>
<tr>
<td>Provide a global environmental perspective</td>
</tr>
<tr>
<td>Develop an understanding of how to integrate environmental criteria</td>
</tr>
<tr>
<td>Provide an understanding of assessment techniques of the environmental impacts of modern technology</td>
</tr>
<tr>
<td>Provide an understanding of the development of environmental policy and its implementation</td>
</tr>
<tr>
<td>Provide an understanding of techniques for formulating and implementing community consultation programs</td>
</tr>
<tr>
<td>Develop the ability to communicate environmental issues objectively and coherently to different audiences</td>
</tr>
</tbody>
</table>
Figure 4.1 Overview of the composition of the questionnaire

The first part of the questionnaire in Appendix I sought to obtain some background on each staff. Specifically, the background information included the following:

• age;
• previous employment;
• teaching experience;
• teaching subjects.

The second part of the questionnaire consisted of a series of 74 survey questions which focused on a different aspects of nine themes.

The questionnaire Figure 4.1 was constructed with 5 statements on the key environmental issues to be covered in engineering degrees, 11 statements on the essential environmental knowledge does an engineer need, 11 statements on the environmental attitudes, and skills are needed by engineers, 10 statements on the key topics to be developed in engineering degrees, 9 statements on the key goals to be developed in engineering degrees, 10 statements on the factors influencing on demand for graduates, 8 statements on the objectives to be covered within an engineering degrees, 10 statements on the communication skills to be developed throughout engineering degrees, 2 statements on the level of importance to be given to sustainability ethics. Items were balanced to expressed positive statements while others expressed negative opinions. This method was employed to improve the trustworthiness of the responses.

Each statement was identified to have contributed towards the decision for a staff to change the directions in the environmental education of engineers either from the literature review or from the research and theoretical content. This was the first step in the search for the causes behind change.
The third part of the questionnaire was concerned about the adequacy of the school curricula existing engineering degrees. Three questions were asked:

• How often are there reviews of curricula in your school or department?

• What were the main recommendations of your most recent review?

• Do you believe the existing degrees in environmental engineering offered by your school or department are adequate for the environmental and developmental needs of societies? Why/why not?

The questions were presented positively to discover what could be done to improve the existing degree programs.

4.2.3 Trial

Three staff from University of Wollongong, took part in the trailing of the questionnaire. After they completed the first section of the questionnaire, the evaluation questions were asked, and the respondents were requested to offer suggestions as to what could be done to improve this section of the questionnaire. The questions were:

• were any of the questions or statements unclear?
• were any of the questions or statements too long?
• were any of the questions or statements too difficult to answer?
• what else can be done to improve this section of the questionnaire?

The trial showed that there was no difficulty with the first section of the questionnaire. The second part of the questionnaire which consisted of 74 multiple choice statements was carefully prepared by each respondent who was asked to indicate in the box provided using three options:

• very clear
• not too clear
• not clear at all

The third part of the questionnaire was subjected to the same test and no staff had any problem in understanding any of the questions. At the end of the questionnaire each respondent was asked if they had any further comment for the improvement of the questionnaire. One of the staff thought that the questionnaire might be a bit long, and yet
the other two thought that those questions were so closely related that they would be better off to remain as they were. The researcher decision was to leave the length of questionnaire unchanged.

4.2.4 Analysis of the survey data

The analysis of the data was divided into 11 sections:

- Characteristic of respondents and general population;
- Assessment of environmental issues to be covered in engineering degrees;
- Assessment of the essential environmental knowledge does an engineer need;
- Assessment of the environmental attitude, and skills are needed by engineers;
- Assessment of topics to be developed in engineering degrees;
- Assessment of goal to be developed in engineering degrees;
- Assessment of the factors influence on demand for graduates;
- Characteristic of the syllabus or courses review;
- Assessment of the objectives to be covered within an engineering degrees;
- Assessment of the communication skills to be developed throughout engineering degrees;
- Assessment of the level of importance to be given to sustainability ethics.

4.2.5 Characteristic of respondents and general population

Two analyses strategies were used with the data. The first categorised the percentages responses according to the personal characteristics of the respondents (Lecturer, Senior Lecturer, Associate Professor, Professor and Assistant Dean) in their responses to the questionnaires. The second scored responses as follows, weighted the response units, four points for first response, three for the second, two for the third and one for the first. From the sum of the scores a rank order was determined. The overall aim of this section was to determine if there was any relationship between the staff rank and their responses. The following variables were also used for comparison of responses:

- age;
- previous employment;
- teaching experience;
- teaching subjects;

Summaries of cross-tabulation tables for these analyses are shown in Appendix II.
4.2.6 Assessment of the environmental education of engineers

The assessment of the environmental education of engineers will be analysed under nine headings in accordance with the nine items identified in the literature review: issues, knowledge, attitude and skills, topics, goal, factors, syllabus or courses review, objectives, communication skills, and sustainability ethics.

The 74 multiple choice questions or statements will be assessed according to the weighted score given to each question and the percentages of the responses compared to the total responses. The four options for each question are:

- most important;
- quite important;
- some importance;
- not important.

The score would range from four points for the most important to one point for not important. Means were calculated and this enabled the researcher to compare responses. These scores were used for ranking those categories. This method was applied to maintain the same rating of scores throughout the 74 multiple choice statements. This is illustrated in Figure 4.1 and in Appendices I and II.

After review of all the open ended responses, the researcher placed them in categories. Given that the wording of ideas varied a great deal, the researcher grouped together in appropriate categories. The most challenging part of the categorisation of responses came when there were ideas which could be placed in one or more categories. The technique was to place such similar idea in the same category. However, when similar wordings increasingly emerged from within the responses, they were placed in a different category. Thus, at times categories were sub-divided while others were collapsed and combined. This whole categorisation process was undertaken with all the open ended question responses.

In summary, there were four outcomes from the analysis of the data. Firstly, a definition of the basic characteristics of environmental engineering education as perceived by staff at various levels and in different subject areas and a clarification of the fundamental concepts associated with the present environmental movement. Secondly, an examination of various courses in environmental studies and the nature and extent of environmental emphasis in other relevant subject areas at tertiary level. Thirdly, definitions for a set of evaluative criteria for environmental engineering education and examination of the nature
and extent of environmental emphasis in a range of educational resource materials. Fourthly, identification of the major trends in environmental engineering education in Australia and examination of the prospects for future development. These data were integrated with an engineering education model in appendix III.

4.2.7 Data collection

4.2.7.1 Questionnaire trials

As previously described, the questionnaire was trialed with three staff members from Faculty of Engineering at Wollongong University. The trials contributed to the trustworthiness of the data because important adjustments were made to some parts of the questionnaires to ensure that they were clear to the respondents.

4.2.7.2 Confidentiality and anonymity assured

The Dean of Faculty of Education wrote a letter to all Heads of Engineering Faculties about the research and the necessity for gaining the correct information from the questionnaires. They were assured that the information from their questionnaires would be confidentially treated, and their anonymity would be guaranteed as statement below.

Please be assured that the answers by your staff will be treated in the **strictest confidence**, and the results will **not** contain information which could identify individuals or individual institutions. All data collected will be coded so individuals and institutions cannot be identified.

The researcher hoped that at least 50% percent of the staff would respond to the questionnaires. In fact, the response rate of the respondents was high because the percentage of the questionnaire that was completed and returned to the researcher, a return rate of 48% percent was achieved.

4.2.7.3 Participant rapport

The willingness of the staff to cooperate with the researcher arose largely from the fact that they had known one another through attending conferences, and as members of the Institution of Engineers Australia. The researcher's good rapport with these staff had contributed in generating the climate of cooperation which enabled the inquiry to be carried out effectively and speedily.
4.2.8 Limitations of the research

The distribution of this survey began on April, 1998 and returns were accepted collected until November 1998. Staff are invited to take part in this national survey of all staff of engineering education at Australian Universities. The survey were completed in the teaching time of the year. Examples from the attached responses of the staff were quite varied:

- Thanks for considering us for your questionnaire. I've looked through it and can't see that it is worth us, as a School of Computing, filling it in as we have no environmental aspects in our courses or likely to have any in the near future.  
  Deputy Head of School.

- I have just been asked by our Faculty's Dean, (and independently by my HOD) to look at this. Before taking the time to complete the survey, I have a number of questions. I wonder if you could answer these for me.
  1. Chemical engineering seems to have been "left off" your list of traditional engineering disciplines - reason for this?
  2. To what extent is your initiative supported by IEAUST?
  3. Who is funding this?
  4. What mechanisms for feedback to contributors?
  5. How do you intend to use the information?
  I look forward to hearing from you.
  Regards.
  Professor of Environmental Engineering
  Department of Chemical Engineering

- As Associate Dean Undergraduate Programs I have received your survey. We have completely redesigned our undergraduate course around the theme of environmental sustainability, so the survey would not do our course justice. Happy to talk to you about it.
  Professor and Associate Dean (Undergraduate Programs)

- Your questionnaire looks excellent, much better than when I first saw it. I don't think that it is appropriate that I fill it in as I am not in an engineering school and we only do service teaching for engineering students.
• Are you still after responses to your survey.
  Please request this information from our professor of Environmental Engineering.
  Department of Civil, Surveying and Environmental Engineering

4.2.9 Trustworthiness of the data

The trustworthiness of the data is perceived to be enhanced by the following factors: credibility of the researcher as an engineer, preference for the researcher to do the survey, confidentiality and anonymity, questionnaire trial, fairly strong participant rapport.

4.2.9.1 Credibility of the researcher

The credibility of the researcher is essentially linked to the fact that he has been an engineer and a teacher, has a PhD in Environmental Engineering, worked in a variety of capacities in different organisations.

4.3 The profile

Profiles were requested from six senior engineering academics, one profile was achieved. The following are a series of topics which I would like you to address in seeking your ideas for solutions and strategies to improve the environmental education of engineers in Australia. These are not exhaustive topics but a guideline to prepare a profile of environmental education of engineers in Australia.

• Environmental sustainable development: This section of the profile deals with environmental issues and problems and relates them to the ESD strategy and policies in Australia.

  - your institution approaches to ESD, and link this to education policy and practice where appropriate.
  - a description of your institution ESD strategy and policy.
  - if possible, a description of specific policy relating to environmental engineering education and training.

• Environmental education of engineers: This section of the profile deals with past and present environmental training of engineers in Australia.

  - a brief history of environmental education of engineers in your institution
  - the institution response to the demand for environmental education of engineering.
- what environmental engineering courses have been offered in the institution. 
This should be an overview if possible, but can draw upon specific examples.

• The future: This section attempts to assess the knowledge gaps, potential demands for, and barriers against the development and promotion of environmental engineering in Australia.

• Skills supply: This section should discuss the demands for and the supply of environmentally educated engineers in Australia.

  - discussion of the current demand for and supply of environmentally educated engineers.
  - discussion of the potential demands over the next ten years, and the ability to meet that demand.
  - if the potential demand cannot be met, give reasons for this. For example, lack of good government policy, poor institutional response to policy, other possible reasons.

• Barriers: This section deals with the problems facing the environmental education of engineers in Australia.

  - discussion of the existing courses in environmental engineering. Are they sufficient given the environmental and developmental needs? What do they lack in terms of existing theory and international best practice.
  - discuss other problems/barriers and issues relating to the environmental education of engineers exist in Australia.

4.4 Summary

The methodology has two active research components: a survey of all Australian universities on the current state and future directions of the environmental education of engineers, and a more detailed written profile produced by senior engineering academics. These empirical and qualitative measures are supplemented by a comprehensive literature and resource review.

In summary, the research methodology is trying to be true to the holistic perspective that this study pursues. This is illustrated in its main features:

  • the extensive coverage of the research questions
• the high response rate to the survey questionnaires
• and the use of the open ended questions.

The trustworthiness of the data is supported by the trialing of the questionnaires by the researcher in order to ensure that possible misunderstandings were avoided.
5.1 Introduction

This chapter seeks to analyse the current state of the integration of environmental education into engineering courses and education institutions throughout Australia. This chapter considers how institutions have adapted their engineering courses in response to the demand for environmentally sustainable development, as well as national government level policies on environment, education and engineering, and changes within the engineering discipline and profession. This chapter examines both the education of environmental engineers and the education of traditional or conventional engineers to understand how and if these disciplines are adapting. These trends are linked to the specific environmental issues and problems facing environmental education for engineers. Options to promote the environmental education for engineers are assessed.

The first section of this chapter deals with the philosophy of the degree whereas in the second section the type of engineer to be developed. The third section focuses on the objectives of the course. The fourth section determines the course structure. The fifth section explores the barriers.

5.2 The Survey

The main objective of the survey was to investigate the status and inclusion of environmental issues and topics in undergraduate engineering education curricula. The survey also elicited the views from academics on what the essential generic and specialist skills and attitudes are needed for a modern engineer. Statistical analysis of the survey results clearly indicates that engineering curricula need to be revised. Faculties of engineering must make provision in their engineering subjects. Teaching and learning material must be updated and capable of enhancing the skills and attitudes of future engineers to meet the changing global environment. The quality of future engineers depends upon preservice engineering curricula.

5.2.1 General background of the research

This research is based on the findings and analysis of a survey questionnaire completed by 48% of the academics approached, and administered by the researcher at the Faculty of Education, University of Wollongong.
The principal objective of the research was to elicit the views of academics, on the topic of sustainable development and environmental engineering education and their importance in general engineering education, and to ascertain what education and training is required to deal with this challenging topic.

5.2.2 Population survey

Table 5.1 provides a summary of the population sample. It includes the number of surveys distributed, the number of returns, and the number of returns as a percentage, and the number of staff teaching Environmental Engineering Education and those not teaching Environmental Engineering Education. The research results and conclusions are based on this sample population.

Table 5.1 The population sample

<table>
<thead>
<tr>
<th></th>
<th>Number of surveys distributed</th>
<th>Number of returns</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Universities</td>
<td>33</td>
<td>16</td>
<td>48.4</td>
</tr>
<tr>
<td>79 Teach EEE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21 Not teach EEE</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5.2.3 Evaluation of the survey

A number of key questions were identified to assist with the analysis of the research, the questions address the following: environmental sustainable development issues and problems, environmental education of engineers, the knowledge gaps, potential demands for, and barriers against the development and promotion of environmental engineering education, skills supplied by different departments, problems facing the environmental education of engineers, Appendix I has the original questionnaire and guidelines.

5.2.4 Environmental issues

Table 5.2 and Figure 5.1 shows that there was interest in the topic of sustainable development and environmental engineering education. 61% of the engineering educators who responded expressed an interest in this area.
There is still a high percentage of engineering educators who continue to pay little attention to these issues. This may be due to the fact that environmental engineering is not thought of as 'hard-engineering', but rather as 'soft-engineering' (Pudlowski et al. 1996).

Academics on the other hand reported that more than (70%) of courses offered in their engineering curricula are dedicated to sustainable development and environmental engineering education. Many academics have also stated that these topics have been introduced into existing engineering subjects but that they are not well covered. Perhaps there needs to be more single-discipline subjects on sustainable development and environmental engineering education introduced in undergraduate programs.

The syllabus and courses reviewed showed that some environmental issues were given coverage during lectures; nevertheless those issues were not covered in great detail. The following education activities and training were mentioned from the 24 programs in the survey of academics:

- Lectures on sustainable development.
- Some elective subjects offered in 2nd year.
- One core subject offered in 4th year.
- Issues concerning the environment and some background to the control, monitoring and modelling of pollution.
- Issues on renewable energy resources.
- Issues in electrical safety eg. effects of transmission powerlines.
- Alternative energy systems eg. biomass, solar.
- Effects of pollution have been discussed and ways in which pollution can be reduced have been taken into consideration during the course at various stages.
- A subject on environmental engineering was introduced in 4th year to civil engineering.
- Issues in energy conservation.
### Table 5.2 Environmental issues

<table>
<thead>
<tr>
<th>Issues</th>
<th>Your rating of issues %</th>
<th>Taught in degree courses offered by your department or school %</th>
<th>Weight Score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1=most important</td>
<td>2=quite important</td>
<td>4 points=most important</td>
</tr>
<tr>
<td></td>
<td>3=some importance</td>
<td>4=not important</td>
<td>3 points=quite important</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5=not detected</td>
<td>2 points=some importance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6=not detected</td>
<td>1 points=not important</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>1 Engineering for sustainable development</td>
<td>79</td>
<td>17</td>
<td>4</td>
</tr>
<tr>
<td>2 The ethics implicit in environmental engineering</td>
<td>79</td>
<td>17</td>
<td>4</td>
</tr>
<tr>
<td>3 The philosophical basis of public concern for the environment</td>
<td>41</td>
<td>25</td>
<td>17</td>
</tr>
<tr>
<td>4 The basic principles of environmental science</td>
<td>62</td>
<td>17</td>
<td>17</td>
</tr>
<tr>
<td>5 The different opinions of scientists, engineers, and the public on environmental issues</td>
<td>46</td>
<td>33</td>
<td>21</td>
</tr>
<tr>
<td>Mean</td>
<td>61</td>
<td>22</td>
<td>13</td>
</tr>
</tbody>
</table>

ND: Not detected
Figure 5.1  Perception of issues for sustainable development & environmental engineering education in undergraduate degree program

- An awareness of the impact on the environment due to engineering projects is promoted in some of the study programs. To make conscious of how engineering decisions affect the environment.

The following initiative were mentioned in the survey of academics in the 24 departments:

Civil - Establishment of a Bachelor of Environmental Engineering and postgraduate research training in environmental engineering.

Civil - Introduction to sustainability concepts in courses in transport planning; offering some environmental subjects in the undergraduate programs eg. water supply & waste water treatment, hydrology, environmental engineering, energy and the environment. Courses in environmental studies include some aspects of sustainable development.
Electrical - Teaching of electrical energy systems; some lectures and research introduced in the area of renewable sources of energy, and masters studies on appropriate technology.

Mining - introducing some reference to environmental impact of processes and waste production, and recycling considerations.

Mechanical - Establishing a 3rd year core subject in energy and the environment; 3rd/4th year elective subject in environmental engineering; some subjects relating to energy efficiency; and a course in public health engineering.

5.2.5 Environmental knowledge

Table 5.3 and Figure 5.2 indicate that the staff allocated a low score to this question (42%) showing that the field of environmental knowledge is in their view, particularly not relevant to the hard core of engineering education. It shows that the academics put, knowledge of environmental economic management for sustainability, and knowledge of environmental precautionary principles in the least category (29%) of responses. Knowledge of the environmental setting of an engineering problem incorporated by 24 respondents, (54%) and was highly rated.

Knowledge of monitoring procedures and assessment standards of environmental quality-The responses provided by the academics as follows:

- 46% most important
- 29% quite important
- 21% some importance

There is variation among responses but 46% of the population thought that the topic was most important. However there is still a high percentage of engineering educators who place little importance on this topic. This may be due to the fact that this type of knowledge is not thought of as 'hard engineering', but rather as 'soft engineering'.

Knowledge of relevant environmental legislation and policy, 37.5% of the staff responding to this topic indicated that they are interested in expanding and supporting the topic. 37.5% regarded it as quite important. Many academics have also stated that these topic are been taught in existing engineering subjects (67%).

Chapter 5: Results and Discussion
The results suggest that knowledge of environmental design and cleaner production is important. Staff are interested in teaching of environmental design and cleaner production topics 46% of responses and 75% of the educators taught the topic. May be it is a signal that more topics within this field should be planned in current engineering degree programs.

With respect to knowledge of environmental economic management for sustainability, 29% of the academics indicated that they are not interested in expanding and supporting the topics. 46% rated quite important, but half of the academics have also stated that these topic have been taught in existing engineering subjects, the other half indicated they are not taught.

Knowledge of environmental risk assessment and knowledge of occupational health and safety-the results suggest that academics are interested in this topic (54%) of responses. Also 83% of the respondents taught the topic in their degree courses.

There appears to be limited coverage of environmental precautionary principles with only 29% of staff reporting inclusion of this knowledge. There may be a need for development of new curricula that would reflect this important topic in engineering.

Knowledge of environmental life cycle analysis—there is still high percentage of engineering educators who continue to pay little regard and attention to this topic (33%) of responses. This may be due to the fact that, it is a new topic for 'hard engineering'.

Knowledge of environmental management procedures, 33% of the staff responding that they do not teach the topic. 42% rated the topic as quite important, this could represent a difference of opinion as to what they respectively perceive to be environmental management procedures. 54% slightly more than half of the academics have also stated that this topic has been taught in existing engineering subjects; the rest indicated it is not taught. This indicated that this topic needs to be considered in revised curricula.

Knowledge of the role of the engineer in the society. 58% of academics rate this as most important, and 87% taught it in degree courses offered.
### Table 5.3 Environmental knowledge

<table>
<thead>
<tr>
<th>Items</th>
<th>Knowledge</th>
<th>Your rating of knowledge %</th>
<th>Taught in degree courses offered by your department or school %</th>
<th>Weight Score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1=most important</td>
<td>2=quite important</td>
<td>3=some importance</td>
</tr>
<tr>
<td>1</td>
<td>Knowledge of the environmental setting of an engineering problem</td>
<td>54</td>
<td>46</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>Knowledge of monitoring procedures and assessment standards of environmental quality</td>
<td>46</td>
<td>37.5</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>Knowledge of relevant environmental legislation and policy</td>
<td>37.5</td>
<td>37.5</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>Knowledge of environmental design and cleaner production</td>
<td>46</td>
<td>46</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>Knowledge of environmental economic management for sustainability</td>
<td>46</td>
<td>46</td>
<td>4</td>
</tr>
<tr>
<td>6</td>
<td>Knowledge of environmental risk assessment and knowledge of occupational health and safety</td>
<td>54</td>
<td>54</td>
<td>4</td>
</tr>
<tr>
<td>7</td>
<td>Knowledge of environmental precautionary principles</td>
<td>29</td>
<td>29</td>
<td>4</td>
</tr>
<tr>
<td>8</td>
<td>Knowledge of environmental life cycle analysis</td>
<td>33</td>
<td>33</td>
<td>4</td>
</tr>
<tr>
<td>9</td>
<td>Knowledge of environmental management procedures</td>
<td>33</td>
<td>33</td>
<td>4</td>
</tr>
<tr>
<td>10</td>
<td>Knowledge of the role of the engineer in the society</td>
<td>58</td>
<td>58</td>
<td>4</td>
</tr>
<tr>
<td>11</td>
<td>Knowledge of the impact of engineering technology on social structure and culture</td>
<td>46</td>
<td>46</td>
<td>4</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>42</td>
<td>38</td>
<td>2</td>
</tr>
</tbody>
</table>

ND: Not detected
Knowledge of the impact of engineering technology on social structure and culture—46% of responses supported the topic. 25% indicated that some was of importance, this could represent a scatter of opinion as to what they respectively perceive to be the impact of engineering technology on social structure and culture. However, 79% of the academics have also stated that this topic has been taught in existing engineering subjects, this clearly indicated there is less discrepancy related to that topic between the staff, this topic should be included, and considered, in engineering education to enable engineers to find solutions to solving engineering problems.

5.2.5.1 Changes in engineering curricula

In the past, the role of engineering education was well defined by the technology. Engineering graduates were basically fulfilling the role of professionals preoccupied with technology and production processes. The last three decades have seen fundamental changes taking place in engineering education that have altered the traditional roles once carried out by professional engineers.
Dramatic changes in social values and beliefs and the tremendous impact of technology on the environment have influenced the change in engineering education, where a predominantly single discipline has become a multi-disciplinary one. Engineers are now expected to be multi-skilled to succeed in their profession.

The environment has become an important issue, where the community is well informed of the negative changes and is generally concerned about them. In this period, environmental issues, such as the depletion of the ozone layer, greenhouse emissions, the rising incidence of skin cancer, photochemical smog and acid rain, have had a tremendous impact on the community.

At the same time, engineering education remains fairly unresponsive to environmental, technological and social changes as indicated by the above results. Yet, future engineers will be forced to use safe and environmentally sound technology, and to adopt sustainable solutions in their projects.

The work of engineers has a direct impact on the ecosystem, therefore, it is essential that sustainable development and environmental knowledge are both included, and considered, in engineering education to enable engineers to find sustainable solutions to solving engineering problems.

According to van Kasteren, this is especially important for engineers, who are seen both as problem causes and problem solvers (Van Kasteren, 1996).

Therefore, all engineers need to be trained in the fundamental principles and practices of engineering, as well as needing to acquire a comprehensive understanding of global environmental knowledge and the consequential effects of technological change on the environment (Cawsey, 1996). Humankind must keep control of how much it consumes minerals, oil, coal and what it returns to the environment, as one day we may be faced with the situation that our planet's resources and environment are not enough to sustain life for the 11.5 billion people predicted in the year 2200. Therefore, engineers have a special and leading role in developing a sustainable future.

5.2.5.2 Issues of environmental knowledge in future engineering education curricula

There are issues of importance to environmental knowledge which have emerged from the data that must be addressed in future engineering education curricula. Those issues
may be divided into five general categories as indicated by the academics and subsequently categorised by the author:

- **Knowledge of sustainable technology**
  - environmentally friendly,
  - cleaner technology and production,
  - energy efficient design,
  - life-cycle analysis from production to disposal.

- **Knowledge of sustainable energy**
  - renewable energy sources,
  - energy efficiency.

- **Knowledge of sustainable management of environment**
  - waste minimisation,
  - recycling,
  - re-use.

- **Knowledge of sustainable use and consumption of non-renewable resources**
  - preservation methods,
  - conservation methods.

- **Knowledge of sustainable policies**
  - environmental policies which deal with the preservation and protection of the environment from any potential threat,
  - environmental impact assessment,
  - economic policies which deal with distribution of wealth and poverty,
  - social policies which concern population and human health issues.

The data emerged that, what is needed is a uniform and general curriculum that can easily be adjusted and applied, and which will take into account the issues and topics of environmental knowledge and sustainable development. An engineering curriculum should not simply be limited to the process of creating specialists engineers. It should go a step forward by creating specialist engineers who are not only environmentally
conscious, but who are also able to apply environmental knowledge and sustainable engineering solutions and practice.

5.2.5.3 Skills and attitudes required for engineers to meet changes in the engineering profession

A question that frequently occurs to engineering students is what are engineering employers looking for when employing engineers? Responses from industry to this question in an earlier survey by Pudlowski et al. (1996) included the following unrealistic view: We require an engineering graduate with an equivalent of a person with 10 years experience. And the following broad, though realistic view: We require a person with motivation and leadership skills, who is creative, a good team member, risk taking and decisive (Pudlowski et al. 1996; Nguyen et al. 1997).

5.2.6 Environmental attitudes, and skills

Table 5.4 and Figure 5.3 presents the respondents' perceptions of the relevant generic qualities and attitudes necessary for the development of a professional engineer.

There were eleven generic skills and attitudes, for respondents to select from; Figure 5.3 present the results for each skill and attitude. Table 5.4 shows the experimental data represented in the figures as a ranking out of 100.

Figure 5.3 indicates that academics are more or less in agreement as to what generic skills and attitudes are required for the creation of a modern engineer, although the relative importance they place on each quality does vary. Academics consider quantitative and qualitative assessment skills to be of most significance (71%) of responses. They have placed more emphasis on technical knowledge and skills with management (67%) of responses. Most of the academics give a lower rating to an understanding of the complexity of the biosphere.

Further studies are needed to follow up this issues. The following is a list of the specialised skills and attitudes which were ranked by academics. These qualities were included in the survey to assist in defining precisely what skills and attitudes an engineer is expected to possess.
### Table 5.4 Environmental attitudes, and skills

<table>
<thead>
<tr>
<th>Items</th>
<th>Attitudes &amp; skills</th>
<th>Your rating of attitudes &amp; skills %</th>
<th>Taught in degree courses offered by your department or school %</th>
<th>Weight Score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1=most important</td>
<td>2=quite important</td>
<td>3=some importance</td>
</tr>
<tr>
<td>------------------------------</td>
<td>---------------------------------------------------------</td>
<td>------------------------------------</td>
<td>---------------------------------------------------------------</td>
<td>--------------</td>
</tr>
<tr>
<td>1</td>
<td>A commitment to environmental sustainability</td>
<td>67</td>
<td>29</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>A commitment to global responsibility</td>
<td>50</td>
<td>42</td>
<td>8</td>
</tr>
<tr>
<td>3</td>
<td>An appreciation of the complexity of the biosphere</td>
<td>33</td>
<td>38</td>
<td>25</td>
</tr>
<tr>
<td>4</td>
<td>An appreciation of uncertainty, complexity, and change</td>
<td>33</td>
<td>46</td>
<td>21</td>
</tr>
<tr>
<td>5</td>
<td>The development of a systems approach to design and management</td>
<td>67</td>
<td>25</td>
<td>8</td>
</tr>
<tr>
<td>6</td>
<td>The development of skills in quantitative and qualitative assessment</td>
<td>71</td>
<td>17</td>
<td>8</td>
</tr>
<tr>
<td>7</td>
<td>The development of skills needed to deal with complexity</td>
<td>46</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>8</td>
<td>The development of skills needed to take a long term view of projects</td>
<td>46</td>
<td>42</td>
<td>12</td>
</tr>
<tr>
<td>9</td>
<td>The development of skills needed to apply criteria against which to assess proposals</td>
<td>54</td>
<td>42</td>
<td>4</td>
</tr>
<tr>
<td>10</td>
<td>The development of skills needed to apply the guiding principles from ethical practice</td>
<td>46</td>
<td>37</td>
<td>17</td>
</tr>
<tr>
<td>11</td>
<td>The development of skills needed to relate and understand environmental issues, beyond an engineer's immediate specialisation</td>
<td>46</td>
<td>33</td>
<td>13</td>
</tr>
</tbody>
</table>

**Mean**

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>ND</th>
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<th>No</th>
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<th>3</th>
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<td>13.2</td>
<td>0.7</td>
<td>1.1</td>
<td>64</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

ND: Not detected
Figure 5.3 shows the ranking of specialist skills and attitudes in the generic class technical knowledge and skills. The figure suggests that academics feel that engineering curricula should provide engineers with a balance of environmental engineering theory and practice and basic environmental science subjects. Intellectual environmental skills are defined to include the following:

- The development of skills in quantitative and qualitative assessment
- The development of skills needed to deal with complexity
- The development of skills needed to take a long term view of projects
- The development of skills needed to apply criteria against which to assess proposals
- The development of skills needed to apply the guiding principles from ethical practice
- The development of skills needed to relate and understand environmental issues, beyond an engineer's immediate specialisation

Figure 5.3 indicates that academics gave a high ranking to dealing with complexity and taking long term view of projects, 46% of academics gave a high ranking to item 10, criteria to assess proposals and ethical practice, understanding beyond specialisation.
However 33% gave a low ranking to item 11, issue of complexity and uncertainty. This may indicate that academics do not regard item 11 as very important.

Environmental attitudes has been defined in the survey to include:

- A commitment to environmental sustainability
- A commitment to global responsibility
- An appreciation of the complexity of the biosphere
- An appreciation of uncertainty, complexity and change

Figure 5.3 indicates that the top two specialist skills and attitudes in this category are commitment and appreciation. Staff places more importance on commitment rather than on appreciation, which suggests that the ideal engineer must be capable of doing the work and committed to the environment, as well as practicing his/her profession with integrity. However academics have ranked appreciation of complexity and uncertainty as lower.

Standards of engineering practice is defined to embrace the following:

- The development of skills needed to apply criteria against which to assess proposals
- The development of skills needed to apply the guiding principles from ethical practice

Figure 5.3 indicates that staff consider understanding of environmental criteria and environmental ethics to be a moderately important specialist skills and attitude. It can also be observed that these skills are not highly regarded by academics (54%) of responses. Familiarity with such criteria and ethics are perhaps less relevant in a tertiary environment education and more useful and commonly applied in the practical industrial environment.

Business practices consist of the following specialised skills and attitudes:

- The development of skills needed to deal with complexity
- The development of skills needed to take a long term view of projects

Just under half of the staff have shown less interest in these issues. Providing relevant business subjects, such as finance, economics and marketing, may prepare engineers to operate and succeed in these issues in the global market.

In summary an analysis of the data gathered through this survey suggest that the most essential generic skills and attitudes of a modern engineer are technical knowledge and skills and attitudes. The emphasis given to personal and professional attitudes by the
academics indicates that engineers are not only expected to be technically proficient in the field but also to know how to behave and operate within an organisation. Other generic groups such as intellectual skills and standards of engineering practice were also highly regarded by staff.

It can be said that the ideal engineer must possess sound knowledge of fundamental environmental engineering principles and laws, and must be able to apply the knowledge and convert theory into practice. The engineer must be skillful and practical in the chosen field. The research also indicates that there is growing demand for engineers to understand the impact of their work on the environment and to be able to find environmental solutions to minimise or prevent damage to the environment.

The ideal engineer must be able to keep control of the quality of the product, which requires familiarity with auditing and checking procedures, and must understand the common language of engineers and have a broad understanding of economic and political structures and the relationships between different countries. Advantageous skills and attitudes include: loyalty and honesty, an understanding of the engineer’s role within society, the ability to think logically, to solve problems and to be dedicated/devoted to his/her work. The ideal engineer is expected to possess a diversity of skills and attitudes, with technical competency balanced by non technical competency.

Engineering educators need to acknowledge this diversity in engineering curricula and provide an education which instills these skills and attitudes identified by the survey. In the long term, engineers can only benefit from the possession of these qualities as they will be more competitive in the global market; to succeed in an era of rapid changes and fierce competition engineers must be of the highest quality and must meet the market’s requirements.

5.2.7 Environmental topics

From Table 5.5 and Figure 5.4 it can be seen that academics show less interest in the expansion and support of education programs in sustainable development and environmental engineering education topics. Slightly less than half of the academics have shown no interest in the expansion of such programs.

Those staff who responded negatively were asked whether Sustainable Development and Environmental Engineering Education taught in the engineering undergraduate
curriculum. A large proportion of staff (nearly 61%) responded that subjects dealing with these topics and ideas are already taught in their department or school.

Syllabus and courses review shows that some environmental topics were given coverage during lectures; nevertheless these issues were not covered in great detail. The following education activities and training were mentioned:

- Topics of pollution and various emission gases.
- Topics of sustainable energy - managing energy sustainably.
- Topics of sustainable management - sustainable forest practice, environmental management, risk minimisation, recycling, waste management.
- Topics of sustainable technology - cleaner production, energy efficient design, environmentally-safe technology.
- Topics of SD&EE education - training courses in environmental awareness, training on environmental issues.

Staff emphasised that more subjects on the following topics were desired in engineering degrees:

- Understanding the impact on the environment of waste generated from engineering processes.
- More emphasis needed on energy-efficient design.
- Re-engineering procedures to consider the environment.
- More information given on how engineering works affect the environment.
- Handling of radioactive materials and how to safely dispose of the waste-material.
- Recycling materials used in engineering.
Table 5.5 Environmental topics

<table>
<thead>
<tr>
<th>Items</th>
<th>Topics</th>
<th>Your rating of topics %</th>
<th>Taught in degree courses offered by your department or school %</th>
<th>Weight Score</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1=most important</td>
<td>2=quite important</td>
<td>3=some importance</td>
<td>4=not important</td>
</tr>
<tr>
<td>1</td>
<td>System approaches to environmental problems</td>
<td>46 42 4 8</td>
<td>54 33 13</td>
<td>44 30 2 2</td>
<td>78 4</td>
</tr>
<tr>
<td>2</td>
<td>Problem solving approaches</td>
<td>71 25 4</td>
<td>87 4 9</td>
<td>68 18 1</td>
<td>87 1</td>
</tr>
<tr>
<td>3</td>
<td>Government environmental policy and legislation</td>
<td>42 29 25 4</td>
<td>70 20 10</td>
<td>40 21 12 1</td>
<td>74 6</td>
</tr>
<tr>
<td>4</td>
<td>Communication with other professionals</td>
<td>62 21 13 4</td>
<td>79 13 8</td>
<td>60 15 6 1</td>
<td>82 3</td>
</tr>
<tr>
<td>5</td>
<td>Local, regional and global environmental problems</td>
<td>50 29 17 4</td>
<td>62.5 25 12</td>
<td>48 21 8 1</td>
<td>77 5</td>
</tr>
<tr>
<td>6</td>
<td>Environmental economics</td>
<td>38 29 29 4</td>
<td>41 45 14</td>
<td>36 21 14 1</td>
<td>72 8</td>
</tr>
<tr>
<td>7</td>
<td>Ecological understanding</td>
<td>38 33 25 4</td>
<td>50 33 17</td>
<td>36 24 12 1</td>
<td>73 7</td>
</tr>
<tr>
<td>8</td>
<td>Appreciation of a range of different value systems in understanding</td>
<td>29 33 38</td>
<td>45 38 17</td>
<td>28 24 18 1</td>
<td>70 9</td>
</tr>
<tr>
<td></td>
<td>environmental issues, social issues and policy</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Environmental law and policy issues</td>
<td>38 33 21 8</td>
<td>50 41 9</td>
<td>36 24 10 2</td>
<td>72 8</td>
</tr>
<tr>
<td>10</td>
<td>Sustainable development concepts</td>
<td>67 25 8</td>
<td>66 20 14</td>
<td>64 18 4 2</td>
<td>86 2</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>48 30 18 3.6 0.4</td>
<td>61 27 12</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

ND: Not detected
Environmental topics Identified by Academics

Figure 5.4 The percentage of academics who agree to the inclusion of topics of Sustainable Development & Environmental Engineering Education in engineering content

- Importance of biodiversity and the impact of its destruction.
- Waste management, recycling and handling of hazardous materials.
- More subjects on renewable energy sources.

Table 5.5 indicates that topics of most common interest among academics. The data most reflects their concern about problem solving approaches, followed by sustainable development concepts, and communication with other professionals. Academics placed less emphasis on environmental economics and an appreciation of the range of different value systems in understanding environmental topics, social topics and policy.

Academics, indicated that sustainable development and environmental engineering education are particularly relevant to chemical and civil engineering, with less need in electrical and mechanical engineering. Many who completed the survey did comment that these topics are important for all engineering disciplines and that they would like to see them integrated into all disciplines.
Academics stressed the importance of including other topics concerning design development and waste avoidance and waste minimisation, as indicated by this quote from the survey:

A business operates to make profit, and to maximise this it is intrinsic that the reduction in waste, be it consumed or generated, must be minimised. All the above can be addressed if equipment is designed at the outset with all these element being considered.

The majority of academics indicated that they would prefer to have such topics run as undergraduate programs, either integrated into the existing subjects or as separate single-discipline units.

5.2.7.1 Discussion

The survey revealed that the majority of engineering staff who contributed to the survey do value the status of the environment and do appreciate the notion that their future engineering teaching can grossly affect the environment. Before graduates can learn how to take responsibility for, and to reduce the impact of, their work on the environment, they must first understand the origins of the problem and how engineering work contributes to it. This cannot be achieved if engineering students are not receiving proper environmental education as part of their engineering studies.

The academics regards this as an important issue in engineering education, as stressed by an electrical engineering staff member, "Environmental awareness and ways to protect the environment should be incorporated into all engineering disciplines".

A very high proportion of staff stated that currently there was very little or no education and training offered in undergraduate degree programs in the areas of sustainable development and environmental engineering. At the same time such focus is regarded as an important topic by the staff. Academics agreed that there should be more environmental topics introduced in undergraduate engineering. This is an indication that engineering education curricula have yet to address sustainability in the design, implementation, application, operation and construction of engineering projects and technology. This is a challenge which must be met by engineering educators.
In 1991 the WFEO recommended that there was a need to provide sufficient content in engineering education to ensure that graduates have a mature understanding of environmental values and an ability to identify, manage and incorporate these values into development projects (Bandler, 1989).

Staff indicated that addressing environmental issues and topics is particularly important for chemical and civil engineers. The reason for this could be a perception that only the work of chemical engineers relates to the environment as they are involved in the treatment of wastes generated in chemical plants, water treatment, etc. Civil engineers are also seen as relevant to the environment due to their work on industrial structures, buildings and systems. The two groups are seen as the most prone to making changes to the environment.

Considering the impact of the work of electrical engineers on the environment with their high-voltage lines, floating electric currents, magnetic and electric fields, they too should be made more aware of environmental issues and sustainable development, and yet there is very little coverage of these issues in electrical engineering curricula. As Choi and Pudlowski have pointed out, electrical engineers have much potential to contribute to environmental quality improvement, especially in the area of energy conversion and storage, environmental variables measurement, remote sensing and detection, and designing computerised environmental protection systems (Choi & Pudlowski, 1994).

Students should be made aware of the issues and ideas concerning the environment and the impact of new developments on it as early as possible in their education, with the objective of raising their interest in, and appreciation for, the environment and its protection. Through industrial visits and practical terms spent in industry, students should be encouraged to make themselves familiar with new approaches to sustainable development and environmental protection undertaken by industrial organisations. Industry recognises its responsibility for the environment and is keen to be involved in environmental education and training (Nguyen et al. 1997).

It can also be observed that academics have a major concern for the environment, especially within the areas of waste minimisation/recycling, water quality/water pollution and the handling of hazardous materials. It has been found that staff strongly support the introduction of environmental protection, environmental management, resources management, alternative energy resources and consumption of natural resources in engineering education curricula. Many staff have indicated that they are currently engaging in or encouraging education and training within the fields of sustainable energy, sustainable management, sustainable technology and SD and EEE.
In general, staff have recognised and acknowledged the importance of the issue of sustainable development and environmental engineering education in engineering curricula. Staff are slowly responding to the need for changes in engineering curricula.

It should be pointed out at this stage that major changes need to take place in the Faculties of Engineering with the introduction of the new curriculum from 2000. In particular, the new curriculum in an engineering context should have a major focus on, and treatment of, the issues of engineering interaction with the community, environmental factors, and it also should have a large section on sustainable development and life cycle analysis (Brisk, 1997).

It is envisaged that a comparative study should be carried out using this survey questionnaire three to five years time. The objective of this second survey will be to determine how the changes in the curriculum developed students' appreciation of the issues, topics and ideas concerning environmental engineering and sustainable development.

Such changes have also been discussed in Australia in the recent Review of Engineering Education. One such proposed change is the provision of parallel streams: a four year environmental engineering program and adapted program in the usual specialist areas (Task Force Report's, 1996).

The results of the survey provided the researchers with some insight into the views of academics on sustainable development and environmental engineering education. It can be concluded that staff have a major concern for the environment, especially within the areas of waste minimisation/recycling, water quality/water pollution and hazardous materials.

Since the role of staff is so essential to the professional development and experience of the graduate engineer, and since staff are the primary developer of engineers, they must be given strong incentives to participate closely in the redesign of curricula, the improvement of methods of education and training of professional engineers who are multi/cross skilled.
5.2.8 Goals of engineering degree

The goals need to be consistent with the philosophy and type of engineer to be educated. There are basic course goals which should be common to all environmental engineering courses, although they can, and should, be applied according to the overall direction of the course. These goals are presented in the following table and should lead to specific skills development, as shown below.

Other goals more specific to each particular course also need to be developed. This would necessitate developing the underpinning philosophy first, then integrating the philosophy into sustainable design and operation. Such philosophy might include:

<table>
<thead>
<tr>
<th>Course Goals</th>
<th>Aim</th>
<th>Rationale/Skills Developed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Provide core engineering skills.</td>
<td>To produce engineers (IEAust Category 2-4)</td>
<td>Develop engineering skills. Graduates must have the skills of engineers.</td>
</tr>
<tr>
<td>2. Develop a satisfactory scientific base.</td>
<td>To underpin engineering knowledge (IEAust Category 1)</td>
<td>Develop breadth of understanding of environmental issues through basic sciences, such as math's, chemistry, biology, ecology etc.</td>
</tr>
<tr>
<td>3. Provide a global environmental perspective.</td>
<td>To develop breadth of issues (IEAust Category 2)</td>
<td>Be able to appreciate the global nature of environmental issues, and that solutions cannot always be made in isolation of other communities, either national or international.</td>
</tr>
<tr>
<td>4. Develop understanding of how to integrate environmental criteria into all stages of design, development and implementation.</td>
<td>To integrate concepts (IEAust Category 3)</td>
<td>Be able to apply basic concepts learnt in different disciplines to all fields of engineering practice, and synthesise new designs accordingly.</td>
</tr>
<tr>
<td>5. Develop understanding of assessment techniques of the environmental impacts of modern technology etc.</td>
<td>To develop professional responsibility (IEAust Category 6)</td>
<td>Be able to assess impacts of proposed and existing projects, and develop any modifications required to improve the project and move towards sustainability.</td>
</tr>
<tr>
<td>6. Develop understanding of environmental and resource management systems, including an understanding of social, political and economic factors.</td>
<td>To develop management skills (IEAust Category 5)</td>
<td>Be able to evaluate and integrate environmental issues in relation to human and physical resources, understanding the different pressures which may restrict or enhance the development of environmentally sensitive solutions.</td>
</tr>
<tr>
<td>7. Provide an understanding of the development of environmental policy and its implementation.</td>
<td>To develop policy (IEAust Category 5)</td>
<td>Be able to analyse existing policy, and devise new policy for a variety of environmental issues.</td>
</tr>
<tr>
<td>8. Provide an understanding of techniques for formulating and implementing community consultation programs.</td>
<td>To develop communication skills (IEAust Category 4)</td>
<td>Formulate and implement programs for developing ability to encourage, assimilate, and assess opinions from a variety of sources. Facilitating stakeholder involvement in decision making.</td>
</tr>
<tr>
<td>9. Develop ability to communicate environmental issues goally and coherently to different audiences.</td>
<td>To enhance communication skills (IEAust Category 4)</td>
<td>Develop excellent verbal/written communication skills including listening, negotiating, conflict resolution, and the ability to work effectively in teams.</td>
</tr>
</tbody>
</table>
impact assessment
- waste management through waste prevention and minimisation;
- clean production;
- life cycle analysis;
- integrated catchment management.

Table 5.6 and Figure 5.5 shows that the results obtained from the staff allocated a high score to this question show that the field of curriculum development and environmental engineering education is in their view, particularly relevant to, chemical and civil engineering disciplines to be at least familiar with the general issues and to take part in protecting and saving the environment. There seems to be no difference in opinion towards the goal of engineering degrees. However it has to be noticed that the staff rate policy to the least category (33%). The Table below shows the individual goals included in the questionnaire that were to be selected, with results shown in Figure 5.5.

The staff respondents were asked to indicate which goals they considered to be of importance for engineering degrees. The following goals are ranked in order of importance as indicated by the staff response, to produce engineers (71%) of responses, to develop communication skills (67%) of responses, to underpin engineering knowledge and to enhance communication skills (58%) of responses, to develop breadth of issues and to integrate concepts (54%) of responses, to develop management skills (50%), and to develop policy (33%) of responses.

The results of the survey indicate that staff require more of its engineers than traditional technical skills; this is a clear signal that engineering training should be revamped. The Institution of Engineers, Australia (IEAust), has long supported a review of engineering education, calling for a broader undergraduate education to include non-technical topics (Connor, 1997).

This section will discuss in more detail what each of the broad goals of qualities and attributes involves. It is hoped that the findings will assist young engineering students, graduates and educators in their discovery of what goals, skills and attributes are needed to practice as a professional engineer today.

From the results obtained, staff rated the provision of core engineering skills (71%) of responses as the most important. For the purposes of the survey, core engineering was defined to embrace the following aspects:
### Table 5.6 Goal of engineering degrees

<table>
<thead>
<tr>
<th>Items</th>
<th>Goal</th>
<th>Your rating of goals %</th>
<th>Taught in degree courses offered by your department or school %</th>
<th>Weight Score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1=most important</td>
<td>2=quite important</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3=some importance</td>
<td>4=not important</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>ND</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>1</td>
<td>To produce engineers (IEAust Category 2-4)</td>
<td>71</td>
<td>21</td>
<td>13</td>
</tr>
<tr>
<td>2</td>
<td>To underpin engineering knowledge (IEAust Category 1)</td>
<td>58</td>
<td>29</td>
<td>13</td>
</tr>
<tr>
<td>3</td>
<td>To develop breadth of issues (IEAust Category 2)</td>
<td>54</td>
<td>25</td>
<td>13</td>
</tr>
<tr>
<td>4</td>
<td>To integrate concepts (IEAust Category 3)</td>
<td>54</td>
<td>33</td>
<td>13</td>
</tr>
<tr>
<td>5</td>
<td>To develop professional responsibility (IEAust Category 6)</td>
<td>63</td>
<td>29</td>
<td>8</td>
</tr>
<tr>
<td>6</td>
<td>To develop management skills (IEAust Category 5)</td>
<td>50</td>
<td>21</td>
<td>13</td>
</tr>
<tr>
<td>7</td>
<td>To develop policy (IEAust Category 5)</td>
<td>33</td>
<td>16</td>
<td>13</td>
</tr>
<tr>
<td>8</td>
<td>To develop policy (IEAust Category 4)</td>
<td>67</td>
<td>16</td>
<td>13</td>
</tr>
<tr>
<td>9</td>
<td>To enhance communication skills (IEAust Category 4)</td>
<td>58</td>
<td>21</td>
<td>13</td>
</tr>
</tbody>
</table>

**Mean** | 56.4 | 23.4 | 8.2 | 12 | 68 | 12 | 20 |

**ND:** Not detected
Figure 5.5 Perception of the coverage of the goals of sustainable development &
environmental engineering education in undergraduate degree
programs

- Engineering skills. Graduates must have the skills of engineers.

- Engineering fundamentals and applications: Understanding engineering
  theories, concepts, and principles and knowing how to apply the knowledge or
  information to real-life practical situations.

- Engineering practice: This is the practical side of engineering, basically a hands-
  on-approach eg. construction of a bridge. It is the actual application of
  engineering knowledge/theory in the field or workshop.

As Page commented:

Teaching is 20% information transfer and 80% psychology, ie. creating the right
attitude to learning and discovery is more important than handing out a copious
amount of notes (Page, 1997).
Providing an understanding of techniques for formulating and implementing community consultation programs was ranked by 67% of the staff as the next important characteristic. Techniques included the following:

- Formulate and implement programs for developing ability to encourage, assimilate, and assess opinions from a variety of sources. Facilitating stakeholder involvement in decision making.

- Communication skills: Is the engineer able to exchange and receive information with other people in the organisation or the public?

While technical skills formation is still at the core of engineering, modern engineering globally is moving into a new paradigm of technological, cultural, social and economic change in which engineers must constantly adapt through acquiring other necessary skills to complement their technical capability.

Staff viewed an understanding of assessment techniques of environmental impacts of modern technology as the third (63%), in importance characteristic. Intellectual skills were defined to cover the following:

- Be able to assess impacts of proposed and existing projects, and develop any modifications required to improve the project and move towards sustainability.

- Problem-solving skills: Is the engineer able to apply knowledge to resolve issues, problems and tasks?

- Logical thinking: Is the engineer able to apply logic in making sensible decisions? It requires following a sequence of steps from basic premises to achieve results?

- Management and organisational skills: Is the engineer able to coordinate or manage a business? Can the person arrange or plan to meet time schedules in a workplace setting?

The next important quality identified by staff was develop a satisfactory scientific base (58%), which included the following:

- Develop breadth of understanding of environmental issues through basic sciences, such as math's, chemistry, biology, ecology.
Science fundamentals: Exposing engineering students to basic science subjects and courses eg. environmental science which can benefit engineering students' understanding of the global environmental implications of engineering applications and technology.

Communication practices were rated 58% and were defined in the survey to be:

- Develop excellent verbal/written communication skills including listening, negotiating, conflict resolution, and the ability to work effectively in teams.

The next important quality ranked by academics was to provide a global environmental perspective (54%) of responses, and to develop understanding of how to integrate environmental criteria into all stages of design, development and implementation (54%). This was defined as follows:

- Be able to appreciate the global nature of environmental issues, and that solutions cannot always be made in isolation of other communities, either national or international.

- Be able to apply basic concepts learnt in different disciplines to all fields of engineering practice, and synthesise new designs accordingly.

- Environmental constraints: Is the engineer aware of the environmental standards that have to be addressed for engineering applications and technology?

- Technical standards: Is the engineer familiar with the regulations, codes of practice and standards imposed on technical procedures?

- Codes of ethics: Does the engineer abide by the standards and codes set by the Institution of Engineers? Is the engineer aware of his or her professional and ethical responsibilities to the community as an engineer?

Understanding of environmental and resource management systems, including an understanding of social, political and economic factors was rated highly by half of respondents. For the purposes of the survey, this was defined as:
• Be able to evaluate and integrate environmental issues in relation to human and physical resources, understanding the different pressures which may restrict or enhance the development of environmentally sensitive solutions.

Policy was rated last by a third of the respondents. This was defined in the survey to be:

• Be able to analyse existing policy, and devise new policy for a variety of environmental issues.

Staff typically seek from engineers a sound knowledge of environmental law fundamentals; an awareness of the law in society, especially international law; as well as other attributes such as patience, honesty, responsibility, motivation, creativity, innovation, risk taking, good leadership and planning skills. As one staff indicated, engineering graduates should be able to convert theory to practice:

Students leave their studies with a strong bias to the theoretical aspects of their chosen discipline. However a more practical hands on understanding needs to be developed and nurtured for their effective transition in the corporate workplace.

The surveys shows that the profile of the modern engineering graduate sought by staff is essentially one who, in addition to having the necessary fundamental technical knowledge and skills, displays strongly positive attitudes, intellectual capacity, sound engineering and business practices.

These findings are consistent with Harrison and Kirkwood, who state that, in addition to basic skills, students have a better chance of success if they have acquired social skills and positive attitudes towards problem solving and goal setting (Harrison & Kirkwood, 1996).

In light of the findings of this survey, it is the duty of educators to produce engineering graduates with such goals, skills and attributes. Unfortunately, such graduates will not be produced if universities remain locked in a conservative mode of thinking. A more realistic approach is needed if this is to be achieved. A first step would be for universities to encourage environmental technologists from industry to be involved in developing engineering curricula.

How should engineering education be designed to meet the needs of both industry and engineering graduates? To achieve this goal, universities must thoroughly review current engineering curricula so as to produce graduate engineers with the skills and attributes...
already outlined. Currently, many universities throughout the world are attempting to confront these problems by re-designing engineering curricula which places too much of an emphasis on technical-based subjects. Educators must leave the traditional ways of preparing engineering graduates behind if their graduates are to operate effectively in the international arena.

As Hadgraft has observed:

if we need to educate graduates with the skills for the competitive working environment of the future, then we need a learning environment which integrates the development of technical and non-technical skills (Hadgraft, 1996).

Non-technical skills that should be developed are listed in the recent Review of Engineering Education Report, Changing the Culture of Engineering Education into the Future. They include communication skills, interpersonal and organisation skills that are necessary for working in teams. In addition, future engineering training is to be aimed at developing high levels of human, economic and environmental capability. The survey shows that staff is supportive of these goals and attributes, and demands engineers who have a broader understanding of the issues which bear on environmental and technical decision-making (Task Force Report's, 1996).

Educators will need to expose engineering students to a greater range of topics and training than hitherto provided in order to ensure engineering graduates are equipped with the necessary diversity of qualities and attributes. What is needed is a broadening and diversification of the skills base and orientation to enhance the attributes required by the society. Educators will not only need to prepare engineering students to tackle the challenges and demands with confidence, but will also need to undertake personal development themselves in order to deliver the required education.

Industry needs its engineering graduates to be economically productive as quickly as possible. It is the duty of educators to train engineering graduates with the relevant skills and attributes along with the capability for life-long learning to meet both industry and society's requirements. However, if we are to meet community expectations, this process has to be evolved in accordance with planned directions involving not only industry and engineering education institutions, but also the professional accreditation bodies and government.
In conclusion, to develop future curricula, engineering educators must employ scientific methods and tools in their work in a similar manner to that employed in their engineering research and development.

Educators must provide students with the highest quality knowledge and skills during their academic years. To achieve this, educational institutions should reduce the technical content and introduce more non-technical and science disciplines to engineering education.

Since the role of industry is so essential to the professional development and experience of the graduate engineer, and since industry is the primary employer of engineers, it must be given strong incentives to participate closely in the re-design of curricula, and the improvement of methods of training and developing graduate engineers who are multi skilled.

The review of engineering education is taking place across the globe. Australian institutions of higher engineering learning cannot therefore avoid this responsibility as the consequence will be the inability for young Australian engineers to compete internationally. The existing engineering curricula needs re-thinking, reviewing and re-structuring to make it more attractive and internationally oriented.

5.2.9 Environmental factors

This section dealt with some of the barriers and problems with existing courses of environmental engineering education. Table 5.7 and Figure 5.6 indicates, there is very little variation between the responses. The main emphasis on the topic of lack of understanding of environmental factors in engineering disciplines. Slightly more than 38% of the population ranked this item as quite important.

58% of academics responded that lack of qualified lecturers was important issue and 33% responded that lack of room in the curriculum was an important issue.

54% academics responded that disciplinary/faculty barriers to co-operation with other environmental educators was quite important. This was one of the main factors effecting the demand for graduates. Perhaps there needs to be more co-operation between departments in environmental engineering education.
## Table 5.7 Factors influence on demand for graduates

<table>
<thead>
<tr>
<th>Items</th>
<th>Factors</th>
<th>Your rating of factors %</th>
<th>Weight Score</th>
</tr>
</thead>
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<tr>
<td></td>
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</tr>
<tr>
<td>1</td>
<td>Lack of government policy</td>
<td>13</td>
<td>29</td>
</tr>
<tr>
<td>2</td>
<td>Lack of political commitment to environmental education of engineers</td>
<td>17</td>
<td>33</td>
</tr>
<tr>
<td>3</td>
<td>Lack of school or department response to policy</td>
<td>17</td>
<td>29</td>
</tr>
<tr>
<td>4</td>
<td>Lack of understanding of environment issues in engineering disciplines</td>
<td>29</td>
<td>38</td>
</tr>
<tr>
<td>5</td>
<td>Lack of qualified lecturers/teachers</td>
<td>8</td>
<td>58</td>
</tr>
<tr>
<td>6</td>
<td>Lack of funds to employ lecturers/teachers</td>
<td>17</td>
<td>42</td>
</tr>
<tr>
<td>7</td>
<td>Lack of funds to develop teaching materials</td>
<td>17</td>
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</tr>
<tr>
<td>8</td>
<td>Resistance in engineering disciplines to environmental education</td>
<td>13</td>
<td>33</td>
</tr>
<tr>
<td>9</td>
<td>Disciplinary/faculty barriers to cooperation with other environmental educators</td>
<td>4</td>
<td>54</td>
</tr>
<tr>
<td>10</td>
<td>Lack of room in curriculum</td>
<td>25</td>
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</tr>
<tr>
<td>Mean</td>
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<td>38.7</td>
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ND: Not detected
Environmental Factors Identified by Academics

![Graph of Environmental Factors Identified by Academics](image)

**Figure 5.6** The percentage of academics who agree to the impact of factors in sustainable development & environmental engineering education in engineering content

It can be seen in Table 5.7 and Figure 5.6 that many academic responses show little interest in environmental engineering education, with half of the academics reporting a low ranking to this aspect of the curriculum.

The question tried to identify reasons why demand might not be met in the context of environmental engineering education. Of those that responded, a few indicated that government policy was a very important problem. One indicated that poor institutional response was also a very important. One stated that the most important barriers were related to the problems with the tertiary education sector; lack of funds for teachers and materials, as well as poor institutional response and a lack of understanding of environmental factors in engineering disciplines. Nevertheless, despite these problems and barriers all members of staff indicated that progress was being made with regard to the environmental engineering education of engineers. Respondents were positive that more courses were being provided and institutions were now responding, in the climate of greater general awareness of environmental engineering education factors. Members of
the staff felt that courses/curricula was being updated in line with current knowledge and policy, despite the lack of regular curricula audits in some departments.

A staff respondent said that despite problems with funding, more schools or departments of environmental science and engineering were establishing and having some impact on environmental education for engineers. He also conceded that although the situation was improving, the situation was not so good in some departments, this might indicate his willingness to assist other staff to bring environmental engineering education of engineers up to a better standard. Another academic stated that more attention has been given to environmental education for engineers, though did not specify whether this attention was governmental, institutional or other.

The survey revealed that the majority of the staff who contributed to the survey do recognise the barriers to the environmental engineering education of engineers and that their future teaching work can grossly affected by the factors influence on demand for graduates. Staff indicated that addressing factors is particularly important for chemical and civil engineers. The reason for this could be a perception that only of chemical engineers relate to the environment as they are involved in the treatment of wastes generated in chemical plants, water treatment, etc. Civil engineers are also seen as relevant to the environment due to their work on industrial structures, buildings and systems. The two groups are seen as the most prone to making changes to the environment.

Considering the impact of the work of electrical and mechanical engineers on the environment, they too should be made more aware of environmental and sustainable development, and yet there is very little coverage of theses in electrical and mechanical engineering curricula.

5.2.10 Adequacy of Syllabus and Course Review

The table 5.8 shows that most of the staff agree that curricula should be reviewed as follows: every 1 to 3 years (62.5%) rank 1, every 4 to 6 years (37.5%) rank 2. The existing degrees in environmental engineering offered by your school or department are adequate for the environmental and developmental needs of societies are rated as follows: (46%) strongly agree ranked 1, (8%) agree and equal number unsure ranked 2 and 3, (13%) disagree ranked 3, and (17%) disagree ranked 4.
Table 5.8 Syllabus or courses review

<table>
<thead>
<tr>
<th>Syllabus</th>
<th>Your rating of reviews %</th>
<th>Weight</th>
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<tr>
<td>How often are there reviews of curricula in your school or department</td>
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<td></td>
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<tr>
<td></td>
<td>62.5</td>
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<td>37.5</td>
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</table>

<table>
<thead>
<tr>
<th>Your rating of adequacy %</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do you believe the existing degrees in environmental engineering offered by your school or department are adequate for the environmental and developmental needs of societies</td>
<td></td>
</tr>
<tr>
<td></td>
<td>46</td>
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ND: Not detected

5.2.11 Proposed objectives

Table 5.9 and Figure 5.5 shows that the responses obtained from the staff allocated a low rank to proposed objectives (45%) of responses. This may indicate that the proposed environmental objectives in their view, relevant to the hard core of engineering education. However, the figure shows that 45% taught such issues, and this may indicate they integrating environmental objectives into their normal program.

The academics give a low ranking to providing an understanding of the development of environmental policy and its implementation. This probably indicates that environmental policy and its implication is given only superficial treatment. Develop a satisfactory scientific base for understanding environmental issues, 58% of respondents indicated that this objective was an important part of engineering education.

Develop core engineering skills, develop an understanding of how to integrate environmental criteria-the responses provided by the staff were as follows:

54% most important
17% quite important
13% and 29% respectively-some important
8% not important

These data indicated, there is variation between the responses of the three categories. 54% of the population expressed an interest in this objective. On a comparative basis there is still a high percentage of engineering educators who continue to pay little regard
## Table 5.9 Proposed objectives

<table>
<thead>
<tr>
<th>Items</th>
<th>Objectives</th>
<th>Your rating of the importance of the objective %</th>
<th>Taught in degree courses offered by your department or school %</th>
<th>Weight Score</th>
<th>Total</th>
<th>Rank</th>
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<tr>
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<td>7</td>
<td>Provide an understanding of techniques for formulating and implementing community consultation programs</td>
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<td></td>
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<td></td>
<td>ND</td>
<td>16</td>
<td>2</td>
</tr>
<tr>
<td>8</td>
<td>Develop the ability to communicate environmental issues objectively and coherently to different audiences</td>
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<td></td>
<td>4 points=most important</td>
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<td>24.1</td>
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</table>

ND: Not detected
to these objectives. This may be due to the fact that this type of objectives is not thought of as 'hard engineering', but rather as 'soft engineering'.

Provide an understanding of techniques for formulating and implementing community consultation programs, 33% of the staff responding to this objective indicated that they ranked this as most important. 33% indicated some importance. Not many (29%) academics have stated that these objective been taught in existing engineering subjects. This aspect is not covered properly.

The results suggest that staff are interested in teaching a global environmental perspective, 50% rate it as most important, 21% quite important, 29% some important. However only 41% of educators have taught the objective.

76% of staff considered the develop an understanding of assessment techniques of the environmental impacts of modern technology, 41% of the staff responding to this objective indicated that they this objective as important. 38% rated it quite important. This could represent a difference of opinion as to what academics perceive to be assessment techniques of the impacts. 45% of the academics have also stated that this objective was taught in existing engineering subjects, 29% indicated it is not taught, which clearly indicated that this objective has not covered properly and deeply.

The ability to communicate environmental issues objectively and coherently to different audiences, responding was ranked by 38% of the staff as the most important. 33% indicated quite important and 25% some important. This could represent a scatter of opinion as to what they respectively perceive to be the impact of communication on environmental issues. However 41% of the academics have also stated that this objective was taught in existing engineering subjects.

This section has dealt with the perceived adequacy of the environmental education of engineers, and some of the problems with existing courses of environmental education. Responses varied widely and were not easily classifiable according to the type of staff member. For example, one responded that the objective matched the needs of development, other indicated that postgraduate education for engineers would be more appropriate, rather than widening the already full undergraduate degree. The dilemma was whether to produce some specialist environmentally educated engineers, or to environmentally educate all engineers.
Environmental Objectives Identified by Academics

Figure 5.7 Perception of the coverage of the objectives of sustainable development & environmental engineering education in undergraduate degree programs

Most of the staff indicated that the environmental education of engineers was improving. One of the staff said that 'providers are more sensitive to the changing training needs for environmental technologies', perhaps again reflecting an overly technocratic approach. Also one of the staff felt that 'society demands, better environmental conditions and government regulation is getting stronger'.

One staff said that the awareness of the need for objectives in environmental education existed at all levels, and said that there have been significant changes in chemical and civil engineering for example, but that mechanical and electrical engineering remained aloof from environmental studies. Another respondent said that there is good will and strategies from professional associations, and some incorporation into single discipline engineering courses. However, many institutions and departments remained insular to changes in environmental engineering education.
5.2.11.1 Staff Proposed Objective

There are a number of objectives in environmental knowledge which must be addressed in future engineering education curricula. These objectives may be divided into five general categories as indicated by the academics and categorised by the author. It was suggested in the data that a suitable course should satisfy the following objectives:

- To foster a view that environmental sensitivity is an integral part of all good engineering.

Environmental considerations are not something of peripheral concern, but are central to the competent design, construction and operation of engineering works. Environmental values should not be optional extras clipped onto a project at great cost after it is fully designed, but must be a fundamental element in project evolution. The objective implies a requirement for knowledge of environmental issues and legislation. It is essential that undergraduate engineers be made aware of potential environmental implications of engineering works. There is a need to engender environmental sensitivity at an early stage in the education process. It is argued good engineering, is inseparable from an awareness of sound environmental principles.

- To achieve a basic understanding of environmental principles.

This objective implies an appreciation of the differences between renewable and non-renewable resources. Engineering undergraduates should be made aware of inter-relationships between different components of the natural and man-made environment. It is probably best achieved by a system approach to environmental education.

- To broaden the horizons of engineering undergraduates.

It would be desirable to expose engineering students to professional disciplines in the social and natural sciences that they would not encounter elsewhere in their courses. Although this contact would necessarily be relatively superficial, it must be made meaningful. It would also be of benefit to allow students to interact with contemporaries from other faculties having different professional backgrounds, training and values.

- To enhance the group interaction and communication skills of engineering undergraduates.
Engineers often have a problem communicating with professionals from the natural and social sciences. This can lead to mis-understanding and conflict when many words are spoken but no transfer of information takes place. A core environmental course could give a unique opportunity to bring together undergraduates from a variety of faculties for group projects. Such a course segment would provide students with a realistic example of the achievement of group results from a number of individuals whom they did not pick a great idea, with expertise with which they were unfamiliar in an overall timetable which they did not set. This will forcibly bring forward the value of group dynamics, communication skills, project organisation and the need to appreciate the perspective of others.

- To provide an appreciation of the importance of values in engineering decision making.

Some engineers tend to approach their professional task with little appreciation of the importance of non-technical factors. Attitudes to man nature relations, for example, are dynamic and affected by a host of cultural and social determinants. Engineering works are carried out in a context of political and economic relationships whose relevance, should be recognised.

In conclusion, what is needed is a uniform pit of general objectives that could be easily adjusted and applied, and which will take into account the objectives of environmental sustainable development. An engineering course objectives should not simply be limited to the process of creating specialists engineers. It should go a step forward by creating specialist engineers who are not only environmentally conscious, but who are also able to apply environmental objective and sustainable engineering solutions and practice.

5.2.12 Communication skills

There have been varying estimates of the amount of time that engineers spend communicating, and numerous studies of the types of writing tasks which they address. This study has attempted to quantify the extent of Australian engineers' involvement with documentation during the course of their work. Documentation in this context refers to both the outcomes of writing projects such as reports, manuals and procedures and the processes which use information as an engineering resource. This research describes the variety and relative popularity of documents and documentation tasks which are used in industry. The results indicate that the types of assessment tasks expected of students
during their studies may not necessarily prepare them adequately for the range of
documentation that is expected of them in the workplace.

It is well recognised that communication is an important aspect engineering work The
most recent National Review of Engineering Education (DEETYA, 1996) once again
encouraged an increased focus on developing communication skills. Its focus, however,
was placed more directly on oral communication and the interchange of ideas between
engineers and the communities they serve. There is no doubt that this is an extremely
important aspect of communication, however, even more vital to engineering work is the
written communication which enables engineers to perform their daily duties.

There has been some research into the types of writing tasks that engineers actually
perform in the workplace (Anderson, 1985; Davis, 1978; Faigley & Miller, 1992;
Winsor, 1989; Winsor, 1994). However, the Australian scene has not received the same
analysis. We could hypothesize that there may be differences in engineering writing
practice in different cultures. With the continual encouragement to improve the
communication skills of Australian engineers, it is obvious that there is a need to study
current communication practice to identify deficiencies and to acknowledge effective
approaches.

While the American studies essentially concentrated on the writing process in engineering
(Anderson, 1985). Preliminary discussions with practicing engineers led me to believe
that they were becoming overwhelmed by the amount and complexity of the
documentation related activities that were integral to their engineering work. They
suggested that they spent between 60 to 80% of their time documenting. We need to
determine how could we better prepare our students for this aspect of their engineering
practice.

5.2.12.1 Discussion

Preliminary research had indicated that the problems engineers perceived with
documentation was that there was too much of it, too little time to handle it, no training
on how to do it, and it kept them from doing the 'real' engineering work.

The number of hours spent in documentation was calculated and a simple average taken.
Engineers spend an average of 36 hours per week in documentation activities. Based on a
40 hour week, this amounts to approximately 90% of their time.
Table 5.10 and Figure 5.8 shows that of the 48% respondents who answered to the question on, which specific communication skills do you think should be developed throughout engineering degrees? 45.2% believed it is very important; 31.2% believed it is quite important; 12.6% some important; and 6.6% not important. It is inferred from the high number of responses that engineers perceive this increasing focus on communication as an important issue.

It is interesting to note that writing technical reports are listed as the most important tasks. Writing letters, faxes, memos ranked 4. Writing skills are not frequently included in engineering curricula. If we assume that elements of critical thinking are inherent in writing process, we can see that this omission is critical.

Reading technical reports ranked third in the list of tasks and reading/using drawings was ranked 2. Reading letters, faxes, memos ranked 5. These conventional tasks remain important to practicing engineers and should continue to be given emphasis in our undergraduate curricula.

Filing and retrieving documentation (Completing forms and check sheets and designing forms and check sheets) are complicated tasks which we are probably not addressing adequately. The unpopular topic of filing and retrieving documentation was listed as the 7th most frequent activity. In conclusion, it is clear that documentation is an integral part of engineering work and that students should skills in, expect to be adequately prepared during their studies for this aspect of their practice. Conventional technical and management reporting provides a solid foundation, this research indicates that a broader scope of communication skills is required.

A closer investigation of reading activities is warranted. Comprehension and analysis skills are obvious components, however, the design of documents being read also affects the ability of readers to quickly and easily complete their task. Documents that are 'user friendly' make the reading task much easier. It would seem appropriate that our curricula should include development of reading and critical thinking skills as well as document design. Problem-based learning activities encourage students to 'read' into the scenario to determine meaning, however, clearly defined 'set' problems allow students merely to perform nominated calculations or prescribed analysis. If we are to adequately prepare our students for efficient comprehension and critical analysis, we must all seek ways to introduce reading activities into our subject areas.
Table 5.10 Communication skills

<table>
<thead>
<tr>
<th>Items</th>
<th>Communication</th>
<th>Your rating of communication skill %</th>
<th>Taught in degree courses offered by your department or school %</th>
<th>Weight Score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1=most important</td>
<td></td>
<td>4 points=most important</td>
</tr>
<tr>
<td>1</td>
<td>Reading letters, faxes, memos</td>
<td>42</td>
<td>33</td>
<td>17</td>
</tr>
<tr>
<td>2</td>
<td>Writing letters, faxes, memos</td>
<td>50</td>
<td>33</td>
<td>9</td>
</tr>
<tr>
<td>3</td>
<td>Reading/using drawings</td>
<td>50</td>
<td>42</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>Reading trade literature</td>
<td>33</td>
<td>29</td>
<td>17</td>
</tr>
<tr>
<td>5</td>
<td>Reading minutes of meetings</td>
<td>29</td>
<td>33</td>
<td>17</td>
</tr>
<tr>
<td>6</td>
<td>Reading technical reports</td>
<td>63</td>
<td>21</td>
<td>8</td>
</tr>
<tr>
<td>7</td>
<td>Reading/Evaluating commercial documents</td>
<td>38</td>
<td>42</td>
<td>12</td>
</tr>
<tr>
<td>8</td>
<td>Reading management reports</td>
<td>38</td>
<td>33</td>
<td>17</td>
</tr>
<tr>
<td>9</td>
<td>Writing technical reports</td>
<td>88</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>10</td>
<td>Filing and retrieving documentation</td>
<td>25</td>
<td>38</td>
<td>25</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>45.6</td>
<td>31.2</td>
<td>12.6</td>
</tr>
</tbody>
</table>

ND: Not detected
Figure 5.8 The essential communication skills as ranked by academics

It is not expect that isolated subjects in communication can possibly address the complex issues embodied in the representation of engineering knowledge. What is required is a contextual model that requires students to learn appropriate methods of documentation for their engineering activities. This approach demands that engineering academics accept the responsibility of teaching the communication skills necessary to their subject area. They should be supported by communication and writing specialists in a similar fashion to technical writing departments in engineering organisations. This comprehensive approach to developing communication skills may be an initial move towards meeting the documentation challenge.

5.2.13 Ethics

Table 5.11 shows that most of the staff agree that ethical development is very important (67%) rank 1. However the actual department rating of ethical development is quite important (46%) of responses. The results indicate there is a gap between what staff perceive and the actual practice of the school or department.
5.2.13.1 Discussion

Engineering education concentrates for the most part on the giving of knowledge. Yet it is capability rather than mere knowledge that characterizes the good engineer. (Elms, 1985)

The characteristics of a professional engineer have been described by Elms (1985)

An engineer must be technically competent, must in some sense render a public service, and must have a certain style or outlook on the world. (Elms, 1985)

The first of these, expertise or capability is clearly a part of a body of knowledge held by the engineer. But knowledge alone does not give capability; there seem to be people with a deal of knowledge and perhaps with high qualifications who are not good engineers. In any case, the relevant knowledge needed changes fast, in some areas with a half-life of as little as five years (Stanley, 1988). One would hope capability is more stable than knowledge.

### Table 5.11 Ethics

<table>
<thead>
<tr>
<th>Your rating of Ethics %</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 2 3 4</td>
</tr>
<tr>
<td>Your rating of ethical development for students</td>
<td>67 29 4 -</td>
</tr>
<tr>
<td>Actual rating of Ethics %</td>
<td>Weight</td>
</tr>
<tr>
<td>Actual rating in your department of ethical development for students</td>
<td>8 46 33 13</td>
</tr>
</tbody>
</table>

Yet in most engineering courses the focuses is squarely on knowledge, on cognitive content and on the instilling of fact and techniques. There are exceptions, of course, but in many of these the additional skills learned are acquired incidentally, almost as a by-product of the central intent of importing knowledge. For instance, in studying mathematics beyond specific subject areas a general mathematical skill is acquired, a way of looking at mathematical problems which is general and not related to any particular set of techniques. Similarly other courses will give problem solving skills, spatial skills, strategies of cross checking and so on. Design courses involve far more than a transfer of knowledge. However, despite such exceptions the underlying assumption is still that it is the primary task of engineering education to impart knowledge and to judge competence
largely by examinations that test knowledge. Teaching for capability is given little emphasis in either theory or practice.

There are a number of reasons for this, some of them good. It is often argued that it is not the proper task of a university to train a student for professional capability. The university should concentrate on the necessary background knowledge as the first part of an engineer's training, the important second part being the time spent in supervised practice before becoming eligible to join an engineering institution. There is some truth in this. There are some skills and attitudes which simply cannot be taught in a university environment as they rely very much on the incentive of real responsibility, in situations where failure could mean financial loss or even a fatality. Nevertheless, the additional ingredients of capability over and above knowledge are, as will be shown, intellectual skills and attitudes of a fundamental nature which are central to the university tradition of scholarship and intellectual rigour.

A related reason sometimes given for lack of concentration on capability is that universities should be producing graduates immediately useful to industry, with the skills and knowledge appropriate to that stage rather than to a later career stage at which a more fundamental capability would be required. This could be called the technician approach.

A practical reason is that it is easier to teach and examine knowledge than capability, and simpler to plan curricula. Further, each staff member in a teaching department will have in mind an absolute minimum set of information in his or her area that any graduate should know. The sum of which for the whole department would involve a teaching time far greater than the total available. There are thus real difficulties in reducing the cognitive content of an engineering curriculum to make way for anything else, no matter how fundamental.

However, a more basic reason for not focusing on capability is that the very nature of engineering capability is poorly understood and often not well defined. Its definition is certainly not obvious and relatively few have attempted it. Very little has been written formally in the philosophy of engineering, in the sense of what engineering is about, despite the practical urgency of the need for its development (Critchley, 1988). This contrasts with the philosophy of science, for which the body of scholarship is very great though there are still serious formal problems concerning the scientific method. Philosophers have been active in a myriad other areas; art, for instance. Why not engineering?
5.2.14 Influence of the biographical variables on staff perception of the curriculum

The influence of the staff descriptor items on perceptions of the importance achievement of curriculum goals was examined with the crosstabulation of the descriptor items by the curriculum items. Differences in responses were found with the following variables:

- age;
- previous employment;
- teaching experience;
- teaching subjects;

Summaries of crosstabulation tables for these results are shown in Appendix II

5.2.14.1 Age

The staff ages were classified into three groups for the purpose of classification. Those aged up to 35 years formed the youngest group, those aged between 36 and 45 years the middle group, and those 46 years and above the oldest group.

The oldest group of staff considered issues, attitudes and skills, topics, goals, and objectives must be included and knowledge, factors and communication skills could be included. The youngest group felt that factors and communication skills were of a higher priorities than the other staff.

A greater proportion of the youngest staff group had four years or more of teaching experience. However, the middle group, in particular, indicated a high incidence of teaching experience of five years or more. This indicates that more staff are now entering the academic profession following completion of studying.

The middle and oldest age groups contained a greater proportion of staff who have stayed longer at their school and who hold executive positions. While this may appear obvious it should be considered that the youngest category can contain staff of age 56. Promotion to executive positions used to be easily accomplished by this age during the years of big expansion of the tertiary education. It would appear therefore that young teaching staff in the schools are able to be influenced by a group of middle to older aged staff, some of
whom hold executive positions and have remained in the schools for lengthy periods of time. It is argued that this breeds conservatism and a tendency to maintain the status quo.

5.2.14.2 Previous employment

In view of claims that staff are inbred, having seldom changed work sites and their effectiveness in preparing students for employment is thus impaired, the effect of this background variable is important. Staff who had a significant term of employment before entering the academic profession showed evidence of different perception towards items which relate to society. These staff gave higher ratings to social awareness which relate to community service and major social issues. They also considered the socially oriented item concerning the environment as more important. Academics with previous employment considered that communication skills levels were not well achieved and gave a low ranking to the achievement of understanding the world of work.

The previously employed group of academics tended to be older and less committed to teaching than the academics who had gone straight to teaching following completion of their higher degree.

5.2.14.3 Teaching experience

The teaching experience were recoded for analysis into a group of less experience who had taught up to and including 10 years and a group of more experience who had taught for 11 or more years.

The less experienced staff felt that the social awareness and understanding the media were more important. They also considered the social discipline items to be more important but it was achieved less than indicated by the more experienced staff.

The more experienced staff considered the social awareness item to be both more important and better achieved than perceived by the less experienced staff. They also considered the achievement of social awareness item concerning the seeking of information and the environmental engineering education item to be better achieved. The more experienced staff indicated a greater commitment to teaching as a career and have stayed longer in their school.

The relationship between teaching experience and teaching subjects will be examined in the following section.
5.2.14.4 Teaching subjects

The teaching subjects of the respondents were recoded into four categories as shown in summary categories of teaching subjects.

The staff of civil/environmental engineering oriented subjects rated many items in the social awareness and academic factors as more important than did staff from other subject areas. The items referred to major social issues and social structures and social systems. They also rated more highly social awareness items, and the communication for practical purposes higher than did staff with other subject orientations.

Staff in the civil/environmental engineering study areas considered environmental engineering education to be better achieved than did the other staff. Staff of the civil/environmental engineering study were also more committed to teaching as a career. Staff of civil/environmental engineering study were more experienced and had stayed in their present school longer.

Crosstabulation (Environmental Attitudes & Skills)

![Crosstabulation Chart]

Figure 5.9 The crosstabulation attitudes & skills as ranked by academics
Crosstabulation (Proposed Objective)

Figure 5.10 The crosstabulation objective as ranked by academics

L : Lecturer
SL : Senior Lecturer
AP : Associate Professor
P : Professor
AD : Assistant Dean

The study shows that all staff are more or less in agreement as to what generic skills, attitudes and objective are required for the creation of a modern engineer. Summaries of crosstabulation tables for these items are shown in Appendix II.
Summary information about subjects of the survey

<table>
<thead>
<tr>
<th>Category</th>
<th>Age</th>
<th>Previous Employment</th>
<th>Teaching experience</th>
<th>Teaching subject</th>
<th>Numb of staff</th>
<th>Percentage of total staff in sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lecturer</td>
<td>36/56 (35)</td>
<td>Surveillance Engineer</td>
<td>L/School of Civil Engineering</td>
<td>Hydraulics Water Resources Material Technology</td>
<td>3</td>
<td>12.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Visiting Lecturer</td>
<td>Visiting Lecturer/Water Engineering (2 years)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Deputy director</td>
<td>L/Faculty of Engineering and Surveying (20 years)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Research fellow Engineer</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Engineer</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Site engineer</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Senior Lecturer</td>
<td>48 (36-45)</td>
<td>Geotechnical Engineer</td>
<td>SL/School of Civil &amp; Environmental Engineering (13 years)</td>
<td>Mathematics Geostatistics Stress Analysis Foundation Engineering Rock Engineering Stability of Slopes Geological Engineering</td>
<td>5</td>
<td>20.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Civil engineer</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Senior geological engineer</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Senior geotechnical engineer</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Associate Professor</td>
<td>57 (46 and</td>
<td>-</td>
<td>AP/Head Department of computer Engineering (23 years)</td>
<td>Embedded Software Design Engineering Programming Real Time Systems</td>
<td>7</td>
<td>29.2</td>
</tr>
<tr>
<td></td>
<td>above)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Professor</td>
<td>59 (46 and</td>
<td>-</td>
<td>P/Chair of Environmental Engineering (30 years)</td>
<td>Hydrology and Catchment Management Scale Issues Remote Sensing Applications Climatic Variability and Erosion Risk Urbanisation and Environmental Impacts</td>
<td>4</td>
<td>16.7</td>
</tr>
<tr>
<td></td>
<td>above)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assistant Dean</td>
<td>(46 and above)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>5</td>
<td>20.8</td>
</tr>
</tbody>
</table>

5.3 The profile

This profile below was submitted by one academic. It synthesis the issues raised by the survey.

5.3.1 The Professional Development of Engineering Educators

The United Nations Conference on Environment and Development (UNCED) and the key document coming from UNCED, Agenda 21, set the world and individual governments on a path to developing green policies and commitments. In Australia, the engineering profession has generally accepted the importance of the concepts of sustainability, as demonstrated by the Institution of Engineers Australia (IEAust) who produced the document Environmental Principles for Engineers (1992). There has been almost no concrete movement to translate these concepts into actions to achieve sustainability, largely because there is a lack of understanding and commitment to sustainability, and also because it is extremely difficult to translate ideas of sustainability into specific actions for individual engineers.

Chapter 5: Results and Discussion
For these reasons, the professional development of engineering educators is essential in the move towards sustainability. This will involve improved environmental education within single discipline undergraduate engineering degrees, and continuing education activities for practicing engineers. This will involve a paradigm shift in thinking on the part of engineers, who must change attitudes and behaviour if the vision of sustainable development is to be achieved, and engineers are to embrace sustainability as a normal part of engineering practice.

5.3.2 Australian strategies

The Australian National Strategy for Ecologically Sustainable Development (NSESD) was released in December 1992 together with the Compendium of Ecologically Sustainable Development Recommendations. The strategy and recommendations cover a wide range of areas and environmental issues, determined by nine working parties. The compendium indicates government responses to the recommendations: there is no specific section on environmental education, but many of the recommendations have implications for education. A range of other important policy strategies followed, all of which had important implications for engineering education. Again though, none of these strategies specifically relate to the professional development of engineering educators. Within the academic engineering profession, these strategies are not widely known and certainly not in any detail.

5.3.3 Institutional responses

The Institution of Engineers, Australia has developed a Policy on Sustainability (1994) and Environmental Principles for Engineers both based on Agenda 21 and the Rio Principles. The IEAust accredits all engineering undergraduate degrees within Australia and has a broad set of guidelines to be used in the accreditation process. No direct guidelines are given concerning environmental literacy or the concepts of sustainable development, although the guidelines do not explicitly preclude these areas. The IEAust Code of Ethics has sustainable development as one of the overarching principles (1994).

The Environmental Engineering Society of IEAust has developed a set of guidelines for the accreditation of Environmental Engineering courses. These guidelines were developed because of the difficulty of judging the suitability of the newly emerging courses. The feature of these guidelines is the adherence to the concept of sustainable development and the multidisciplinary nature of the courses. The Australian Science Technology and
Engineering Council (ASTEC) in a report on developing long-term strategies for science and technology in Australia saw environmental sustainability as one of the key forces for change in the future (1996).

5.3.4 Environmental education of engineers

Following the World Federation of Engineering Organisations lead in their submission to the Earth Summit in 1992, the Annual General Meeting of the Institution of Engineers, Australia, approved the following resolution:

"That Council acknowledge the leadership role the engineering profession must play in attainment of sustainable development and that Council develop special plans to achieve this leadership role and report regularly to the members"

As a result, a Task Force on Sustainable Development was established to develop resource material to help individual engineers achieve sustainability, but to date this project has produced inconclusive results. The IEAust Policy on Sustainability is based on Agenda 21, and recommends actions that lead to sustainability in the practice of engineering by promoting the engagement of individual engineers in assessing and improving their actions in terms of sustainability.

The problem though in implementing these policies is that the traditional undergraduate education of engineers has pointed them in the opposite direction of sustainability and environmental factors. The traditional analytical approach is not appropriate when dealing with holistic complex systems of environmental factors. Engineers must be encouraged to use innovative thinking and to take societies needs into consideration; it must become normal for engineers to put before the client the best option for sustainable development within the terms of reference. For this to occur environmental education must be included at all stages of engineering education. There should be awareness raising seminars for top level managers, middle managers and technicians will require specific courses that target technical problems in their sector, formal graduate degrees are necessary to address the detailed technical solutions relating to particular environmental issues. All these need to be placed in the broader social context of achieving sustainability, to prevent the over-use of "end-of-pipe" waste treatment technologies. For the undergraduate level, environmental education is increasingly important as a way of instilling a sustainability ethic into future generations of engineers.
5.3.5 Traditional (Single-Discipline) engineering degrees

The development of undergraduate environmental engineering courses is partly market driven, but also an admission of failure in the environmental education within engineering degrees. It is easier to create new courses labeled "environmental engineering" rather than integrate environmental education into traditional disciplines. This means that many traditional engineering degrees in Australia are not "environmentally sensitive". An earlier study by Nguyen et al. (1997) demonstrates that even in those courses that had an environmental component, the maximum was 15%. In many courses it was possible to bypass environmental components altogether.

In addition to promoting better and more comprehensive environmental education within these single-discipline degrees, it will also be necessary to develop separate environmental engineering degrees which are multidisciplinary.

5.3.6 Environmental Engineering Degrees

There are 18 environmental engineering degree courses operating in Australia. Most are less than four years old, and most have sprung from the civil engineering departments and are largely based on civil engineering degrees. Most of these courses attract a high percentage of female students and a higher standard of student based on tertiary education entrance scores. The graduates of these courses have readily found employment in a wide range of areas and industries. They are well regarded by industry: one reason suggested for this is that they have a more rounded degree experience and can view problems from broader contexts than single discipline engineering students. Despite these advantages, the degrees in environmental engineering are not spread across the wide range of environmental issues and problems. Even the specific environmental engineering courses need to embrace ESD more wholeheartedly, and also to develop different and more diverse specialisations than those currently available.

5.3.7 Continuing education

In order to expose practicing engineers who have not received environmental education in their formal training, it will be necessary to develop awareness raising courses, and more detailed courses relating to technical environmental issues within specific sectors. This will fall to professional engineering organisations to make this occur. Graduate courses in universities can provide higher level technical skills, while distance education subject
should also be considered by universities. Currently in Australia there are a wide range of continuing education courses relating environmental engineering, but these are largely focused on "end of pipe" waste treatment than implementation of sustainable development concepts.

5.3.8 Skills supply

Despite the availability of environmental education for engineers in Australia, only 25% of graduate engineers have received any environmental education. As this thesis argues all engineers should be environmentally educated, this means a shortfall of 3000 out of 4000 per year, or 30000 over ten years, given the demand for engineers generally is static or falling slightly. Thus it is not a question of market demand for environmentally educated engineers but that institutes must make all engineering graduates environmentally educated.

5.3.9 Barriers to the environmental education of engineers

Several key barriers indicated to the inclusion of environmental education in engineering. These included:

• lack of recognition that environmental engineering education is relevant to all engineers;
• difficulty in getting traditional engineers to think environmentally;
• lack of resources for curriculum development;
• lack of resources for development of teaching materials related to ESD, and
• overloading of existing engineering courses, hence barrier to the inclusion of new material.

Thus engineering faculties and academics themselves are the major barriers to the development of environmental literacy in engineering courses. It is also not enough to insert new options for environmental education, but in some courses examples of environmental issues and problems need to be introduced, as well as new concepts and theories. This will vary from course to course.
5.3.10 Strategies

In terms of achieving change, the most crucial dimension is to change the paradigm of environmental education in engineering. It is argued that one university in each state will develop environmentally literate engineering courses which can then be adopted and modified by other institutions. In the medium to long term, resources should be developed to assist academics to integrate ESD concepts into curricula; this should be done at a state level so the resources can be transferred from state to state.

Professional engineering organisations must provide leadership by promoting environmentally literate engineers and urging engineering institution to include ESD concepts in curricula. Accreditation systems can be used to encourage this. It is Proposed to establish national and state centers for sustainable development, as these could significantly improve information transfer.

5.4 Summary

In summary, the research survey indicated that whilst environmental matters were receiving more attention in contemporary courses, there was a lack of coherent focus in relating these matters to mainstream engineering concerns.

The study identified the major trends in environmental engineering education and suggested directions for future development.

The study identified the basic characteristics of environmental engineering education as perceived by the staff at various levels and in different subject areas in engineering faculties.

The study clarified some of the fundamental concepts associated with the present environmental movement.

The research study examined the nature and extent of environmental emphasis on environmental studies and in engineering education at the tertiary level.

The study defined a set of evaluative criteria for environmental engineering education in engineering courses.

This study suggested the development of appropriate curriculum and approaches to overcome this problem of lack of awareness and training for engineering graduates.
The results of this study demonstrate that staff consider the area of environmental education and the principle of sustainable development to be important and that they should be included in engineering education curricula. This answers the first question of the study as to whether engineers need to be environmentally educated.

The other question of the study was whether these issues are currently being met in engineering curricula. From the data gathered, the situation in Australia is in progress, although there are still problems with application in general engineering disciplines.

The impression that one may get from the responses is that there is insufficient or no coverage of some issues and topics on the environment and sustainable development in engineering education. Based on this, one may conclude that there are problems with the existing engineering curricula and that they need to be resolved as a matter of urgency.

It is evident that future staff must be exposed to, and must learn how to think along the line that, sustainable and ecologically sound engineering is the only option available in creating a sustainable world for all humankind, preventing further degradation of the environment.
Chapter Six

Conclusion

6.1 Where do we go from here?

The 'Williams Report' of 1988 Review of the Discipline of Engineering surprisingly made no mention of environmental issues in engineering education, despite its broad terms of reference and comment that engineering graduates should be concerned with the social implications of their work.

How can engineering educators best respond to these social implications? What environmental components should be included? Should they just deal with 'tools' for environmental management, eg. economic tools, and information 'facts' from science and low, or should they also require students to confront and analyse their own and others' values? How can these issues best be incorporated into the curriculum?

It is suggested in this context that the likely first response will be to 'tack-on' environmental subjects, probably of the 'tools' and 'facts' variety, to already over crowded curricula. It is argued that although this may be a practical first stage response, but it will not provide the intended results in terms of engineering education for environmental responsibility and sustainability.

Since the role of engineers is typically seen as the modification of the environment to meet human needs, it is not surprising that engineering courses have often been at the forefront of discussion in every curriculum reform. The important questions asked in this context are:

i. To what extent have engineering curricula been modified to meet the needs of environmental sustainability?
ii. Has such modification been sufficient and appropriate?
iii. Is there a need to further 'green' engineering curricula?
iv. What type of changes might be required?
v. And finally-Where to from here?
The study identified that one prominent trend in Australia in the last ten years has been the development of environmental engineering courses, generally emanating from civil or chemical engineering departments. These new degree programs are aimed at producing specialist engineers to fill environmental management positions in government or private sector. It was evident that these initiatives were not aimed at meeting the need for enhanced environmental literacy in the engineering profession as a whole.

Indeed some staff suggested that the introduction of the new environmental engineering degrees may be counterproductive for enhancing environmental education for engineers more generally. This may result from the new degrees being seen as an appropriate and sufficient response to 'greening' engineering education. If this explanation has validity that environmental issues become the province of a special group of engineers, and the broader 'greening' of engineering education will be neglected.

Others view the influence of the new environmental engineering degrees quite differently. They see this attention to environmental specialisation as raising the profile of environmental issues within the engineering profession and hence facilitating a serious commitment to 'greening' of standard engineering courses. A key element in this argument is the status accorded to the environmental engineering courses by the high level of competition for entry.

This thesis is not about specialist environmental engineering degrees, but rather is concerned with 'greening' of standard engineering courses. The outcome of this thesis is to assess appropriate responses to achieve such greening. To provide a starting point for addressing this issue it was first necessary to consider the roles and responsibilities of engineers mentioned in paragraph 5.2.8.

'Engineering is a profession which is primarily concerned with modification of the environment. Engineering is a discipline in which the laws of science together with experience are used to mould the material forces of nature into a design which will benefit the welfare of mankind' Kelleher and Stark (1987, p. 33).

Surprisingly the study shows, despite acknowledgment of this role, the engineering profession has been slow to embrace responsibility for the environmental and social consequences that may flow from that modification process. The profession has reacted to social pressures rather than playing a pro-active leadership role. This tardiness is reflected in the extent and nature of inclusion of environmental issues within engineering education to the present time.
This striking lack of attention to education for environmental responsibility for engineers has been remedied more recently by the Institution of Engineers by strong reference to the environment in Code of Ethics and Environmental Principles for Engineers mentioned in paragraph 5.2.8. The Code of Ethics requires that engineers 'recognise the community interest' involving 'attention to the ecological and physical environment, the prudent use of natural and human resources and social, economic and financial impacts of their work'.

Code of Ethics states that:

'The responsibility for the welfare, health and safety of the community shall at all times come before their responsibility to sectional or private interests, or to other members' (p. 3).

Environmental Principles is a comprehensive document which complements the Code of Ethics and emphasises the role of the engineer in developing, applying and promoting a sustainability ethic. The Environmental Principles acknowledge value differences within the community in relation to environmental management and stresses the need for community involvement in the decision making process so that community concerns and values will be 'reflected in engineering solutions'. Accordingly the need for engineers to learn skills necessary to develop active community participation in decision regarding engineering projects is also stressed.

These two documents place environmental issues, including the social context and public participation in decision making, centrally among the responsibilities of engineers. An important question answered by this thesis is the extent and nature of the response by the profession at large, and most particularly engineering educators, to these guidelines.

It is also relevant to ask whether there are other trends and influences to which engineering education should be responding, and indeed the answer is that, engineering education should aim to produce professionals who can participate creatively in the development and application of environmental policy, which after all sets the framework within which engineering practice must take place.

The survey in this study suggested an agreement by the staff, about a common set of principles for environmental management derived from the principles which underpin the concept of sustainability. These include the precautionary principle, protection of biological diversity, maintenance of ecological processes and inter and intra-generational equity. The importance of community involvement in environmental decision making is
also declared. The inclusion of these principles in the engineering curriculum as suggested by the survey in this study, means that the principles for environmental management are progressively try to find their way into the legislation and policy through universities, and hence will increasingly influence the context in which engineering practice occurs. Hence engineers and staff need to understand these principles and to engage in on going discussion about how they may be applied. Importantly declared by the staff, such understanding and application does not derive solely from technical knowledge, but relies heavily on socially derived criteria, as mentioned in paragraph 5.2.4 issues, paragraph 5.2.5 knowledge, paragraph 5.2.6 attitudes, and paragraph 5.2.7 topics. One main comment given by one of the surveyed staff about how should engineering education be designed to meet these needs.

>'If we need to educate graduates with the skills for the competitive working environment of the future, then we need a learning environment which integrates the development of technical and non-technical skills'.

The example given by one engineering educator suggests that, the precautionary principle is applicable in situations of scientific uncertainty, where the environmental impact of a development is likely to be 'serious' or 'irreversible'. However, these latter terms can only be judged against socially constructed criteria-what one observer may regard as 'serious' another may find trivial. Likewise, decisions on how much precaution and what type of precaution should be applied cannot be fully resolved by science. Hence appropriate processes for decision making under uncertainty must be found. Increasingly it is likely that these will need to be transparent and to involve wide public participation. The reliability or integrity of the information on which the decision will be based is also likely to receive increasing attention.

The results in chapter five indicate how engineers participate in this process by teaching the enhanced skills in communication, understanding of the social processes of decision making and of the social construction of the scientific inputs to the decision making processes. Such matters are still yet to be comprehensively covered in engineering education as suggested by the staff.

6.2 Is engineering education appropriate for the present & future environmental responsibilities of engineers?

The argument and conclusion so far has suggested that an appropriate consideration of the environmental impacts of engineering activities is as much a social as a technical
issue. It has been argued that a fairly sophisticated understanding of community values and their ideological bases is required. A temporal focus which covers not only the present but also the interests of succeeding generations is necessary. Spatially, not only local, regional and national issues are relevant, but so too are international and global concerns, as well as understanding the social context in which their profession is to be practiced and its dynamics.

It is concluded that engineers need to appreciate the social construction of the scientific and technical inputs to environmental decision making. It is also concluded that they need skills in communication with the many stakeholders in environmental decisions and in facilitating meaningful participation by these varied groups.

In assessing whether engineering education is providing the appropriate skills and knowledge for these tasks and roles, the thesis has considered these in three broad assertions.

(1) Engineers need to have an awareness of the environmental implications of their professional activities and they need to be at the forefront in this knowledge.

(2) Engineers need to understand the social construction of environmental issues and of the knowledge which informs decision making on these issues.

(3) Engineers need to understand the many individual paradigms which frame environmental concern within the community.

It has been identified that most engineering schools have responded to (1) in some way, generally by adding a subject to the curriculum which examines environmental impact of engineering activities through case study examples, however this does not mean integrated through the curriculum of engineering education.

It is also concluded from the data that most engineering schools have paid little or no attention to (2) and (3) in their curriculum development. It is necessary to make a case for emphasis on the importance of the inclusion of (2) and (3) in engineering curricula since some may argue that the lack of attention to (2) and (3) is appropriate. After all it was suggested by Codner (1993) that engineering curricula are already overcrowded, and is it not best to leave social issues to the relevant experts, the social scientists?

To demonstrate why (2) and (3) are considered important, requires a return to the Code of Ethics and the Environmental Principles which are aimed at guiding engineering
practice. Both these documents contain phrases which are not uniquely defined, but rather depend on socially constructed criteria, as illustrated in the following examples.

From the Code of Ethics

'Professional practice...in ways that recognise the community interest. This includes attention to the ecological and physical environment, the prudent use of natural and human resources and the social, economic and financial impacts of their work' (p. 3).

'The responsibility for the welfare, health and safety of the community shall at all times come before their responsibility to sectional or private interests, or to other members' (p. 3).

How the 'community interest' or 'welfare' of the community is defined will depend on the 'world view' or paradigm of the observer. Put simplistically, for some in engineering faculties the community interest is seen as best served by rapid and profound transformation of the environment through engineering works such that economic growth may be achieved. Continuing economic growth is seen as a necessary pre-requisite for development including improved environmental care. For others such a course may be viewed as unsustainable and hence not in the community interest over the longer term, since among other irreversible environmental impacts it is bound to lead to excessive loss of biodiversity. Likewise, how the 'prudent use' of natural and human resources is defined will depend on the paradigm of the engineering faculties.

From the Environmental Principles

'Engineers need to develop and promote a sustainability ethic'. 'Engineers should practice engineering in accord with a sustainability ethic that leads to sustainable development' (p. 1).

Sustainability is similarly a value laden term dependent on defining criteria such as sustainable for what purpose, sustainable over what time period and in whose interests? A major question in the sustainability debate concerns the substitutability of human made for 'natural' capital. For some sustainability is achieved as long as the stock of 'capital' is constant, regardless of whether the capital stock is 'natural' or human made. For others natural capital-forests, fauna etc., has special qualities and cannot be compared with human made capital such as buildings, roads and dams.
From the Environmental Principles

'Recognise the rights of the community to be involved in project formulation and development and actively encourage such involvement'

'Learn the skills necessary to develop active community participation in engineering activities, taking into account the often inadequate and uncertain nature of environmental data' (p. 1).

Promotion of community involvement requires that the views, values and paradigms of the various sectors of the community are well understood and that participatory mechanisms are constructed in a manner that allows those approaching environmental issues from a range of world views to meaningfully participate.

From the Environmental Principles

'Disclose environmental implications and external costs of engineering activities, taking into account the often inadequate and uncertain nature of environmental data' (p. 1).

As indicated earlier, dealing with uncertainty in environmental decision making is an increasingly important issue. The principles underpinning the concept of sustainability, such as the precautionary principle, are placing emphasis on the need for better understanding of the reliability of the scientific data which inform environmental decision making, including the influence of the social context in which the data are generated. As well there is increasing emphasis on the need for such information to be made available in an appropriate form that facilitates interpretation by lay participants. Such emphasis is placing new demands on the skills and understanding required from engineers.

In sum, it can be seen even from these few extracts that to meet the responsibilities laid out in the Code of Ethics and Environmental Principles engineers need to be well vested in the social context of their work. The complex, varied and equally legitimate views on what constitutes the 'community interest' must be acknowledged and understood.

From the review in chapter three of tertiary environmental education in Australia at chapter three, it would appears that, few undergraduate engineering courses in Australia are adequately meeting this need at present.
While some subjects cover related issues in risk management for example, quantitative risk analysis may once have provided a sufficient basis for risk management of a project. It provided 'objective' information for risk management in engineering projects and input for environmental decision making. However, the 'objectivity' of quantitative risk analysis has come under scrutiny since it is recognised that the inputs to the analysis are influenced by assumptions of the analyst and these components are also affected by the social context in which the risk activity is occurring. Hence the credibility of engineers among the broader community in risk management discussions may depend on their understanding of this social context of risk assessment.

Furthermore, risk perception among the stakeholders is today regarded as of equal importance in risk management as quantitative risk analysis. But understanding of risk perception lies firmly in the realm of the social sciences and requires appreciation of different value positions. Indeed its inclusion in risk management is acknowledgment of the legitimacy of different paradigms for managing risk. Dealing with risk perception requires very different skills from quantitative risk analysis, skills which clearly indicated by the study, lie outside the scope of 'normal' engineering training and hence may seem both challenging and threatening to students and engineering academics. One of the courses in appendix III suggested by the researcher, 'uncertainties and risks in engineering', will be just one step towards such a challenge.

6.3 What curriculum modifications are required to provide appropriate environmental education for engineers?

'One of the most difficult concepts to get across is that there is no such thing as an objective, external real system, but that all systems are constructs of the mind'.

(Elms, 1989, p. 3.)

Reforming curricula to incorporate education for the group of skills and knowledge identified above is extremely challenging. The necessary knowledge and expertise resides firmly in the disciplines of philosophy and the social sciences. It is unlikely that many academics presently in engineering schools are well equipped to teach in these areas and it is probably unreasonable to expect them in the short term, to develop the necessary expertise.

This means that at least in the first instance relevant subject matter will need to be added to the curriculum and taught from outside engineering by appropriately qualified
academics. Whether this takes the form of a 'stand alone' subject or is included as a component of an already existing subject such as 'professional practice', the material is likely to be perceived in same settings as peripheral to the mainstream technical components of the course and consequently of lesser importance.

If, as argued above, the social sustainable context and community input are to be regarded as centrally important aspects of engineering practice, the skills and knowledge necessary for engineers to deal with these issues must be fully integrated into the engineering curriculum such that they appear as an integral part of engineering practice of equal importance to, and inseparable from, the technical aspects.

Whilst such integration may be a laudable long term objective of curriculum reform, a pragmatic assessment leads to the conclusion that it is not possible to move directly to this position from traditional curricula, but rather that a gradual evolution of curriculum design will be required. Such an evolutionary process would mirror the changes that which should take place generally in environmental engineering education involving a move from a descriptive multidisciplinary approach to environmental issues with most emphasis on inputs from the sciences, through to a more analytical, transdisciplinary and problem oriented approach in which the environmental issue is the focus and the social and sustainable context is given due recognition.

In turn these changes have followed progress in analysis of the nature of environmental issues in the literature, and the appreciation and acceptance of the conclusions of this analysis by environmental educators.

6.4 What is the likely route of this evolutionary process in engineering curricula? and where on it are present curricula situated?

The typical first stage response to a 'greening' of the curriculum is to add a subject involving assessment of environmental issues. Generally an environmental impact assessment approach is taken using matrix type analysis of impacts. The biological, physical and chemical impacts on the environment are assessed and social and economic effects are also recognised, but generally receive less attention.

Overall the emphasis in current programs is on objectivity and finding the 'facts'. There is generally no recognition given to the social sustainable construction of the assessment framework. Hence the subjectivity inherent in the exercise is ignored. It also follows that the range of paradigms or world views that provide differing frameworks for analysis
including determination of appropriate criteria and their weighting, are not given legitimacy.

Whilst such subject material may be very useful in developing the skills and knowledge in the first area identified above awareness of the environmental implications of engineers' professional activities. They make no contribution to the second area, and indeed may have a negative effect through denying the role of the social sustainable context in framing environmental assessments.

A first stage may involve use of guest lecturers in order to include some attention to the social sustainable context issues comprising the second area outlined above. However, unless this material is integrated with the rest of the subject such that its messages are reinforced in case studies and examples, its effect is likely to be minimised or even negated.

A further disadvantage with this stage is that in using a one-off subject to cover environmental issues, the environment is likely to be seen as a separate issue not as an integral part of engineering practice. Environmental concerns may be further marginalised if taught from outside the engineering faculty especially if the assessment is such to suggest that the subject is a 'soft option'.

Furthermore a one-off subject situates environmental issues at just one place in the four year curriculum. Where is the most appropriate place? Early in the degree offers the advantage of conditioning students to see environmental considerations as a part of engineering practice, but has the disadvantage that without later reinforcement, this message may be forgotten.

Late in the degree program offers the advantage that students have some experience regarding the technical subject matter of engineering, but has the disadvantage that students have formulated their views on engineering practice without environmental considerations playing a central role. Wherever the subject is situated, its one-off nature will serve to set environmental issues apart from mainstream engineering practice unless the subject matter is reinforced by the integration of environmental concerns into the mainstream engineering subjects throughout the curriculum.

The logical second stage in curriculum development is modification of the environmental subject now present in most engineering curricula to include the social sustainable context issues outlined in the previous section, and integration "infusion" model of environmental...
aspects throughout the curriculum in order to complement and reinforce the knowledge and skills imparted through the separate environmental subject.

It seems necessary to retain such a subject for the foreseeable future in order to provide an appropriate level of knowledge and skills for addressing environmental issues. However, it may be most effective to split the material so that an introduction is provided in first year and more detailed analytical skills are added in say second and fourth years.

But how is this to be achieved? What skills may be necessary to undertake the course reconstruction and subject modification implied by the discussion so far? At least in the early stages assistance in curriculum design from a person with skills in the social sciences and in environmental education for technical specialists seems necessary.

As well specialist assistance in the integration of environmental aspects into the traditional engineering subjects would be required. This latter task may be a protracted one since although some academics will welcome the opportunity to modify their subjects in this manner, others will not be sympathetic to the curriculum changes and will certainly be hostile to changes in the subjects under their control. For these reasons the process of integration is likely to be slow at the start but should gain momentum as engineering staff develop skills in integration and as successful subject modifications are demonstrated. It will require such success to break down resistance to change within sections of the faculty.

6.5 Concluding remarks

There is an urgent need for modification of engineering curricula to incorporate environmental knowledge and skills appropriate for meeting the present and future environmental responsibilities of engineers. These responsibilities have changed dramatically over the past few years in line with trends in environmental management both domestically and internationally. The responses of the professional body, the Institution of Engineers, Australia, regarding the role of the profession in environmental management responsibilities declared in the environmental principles for engineers (1994). No longer is technical knowledge regarding environmental impacts of engineering activities, sufficient to meet these responsibilities. Engineers today are expected to involve the community in decisions concerning the environmental impacts of their work and to do so must understand the social sustainable context of their professional activities.
It is in relation to the social context that expectations have changed most dramatically. Previously, attention to 'social sustainable issues' involved consideration of impacts such as noise, dislocation of a community, employment and other economic impacts, and measurement of these via tools such as cost benefit analysis. In addition engineers are now expected to appreciate community values and to understand that analysis of environmental impacts is itself framed by the social sustainable context and the value system of the observer. The legitimacy of other value systems needs to be acknowledged and the processes of community consultation and decision making on environmental issues structured to include inputs from the full range of paradigms.

The curriculum changes suggested in this thesis as appropriate to meet these needs are significant and extremely challenging and will no doubt meet resistance among already over loaded engineering educators. They have a greater chance of adoption if their benefits can be shown to extend beyond environmental education. The following observations suggest that further benefits are likely to occur.

The Williams Report (1988) on engineering education stressed the need to attract more and better students to engineering schools and a higher proportion of women. The Report and other commentators have highlighted the importance of engineering to national development and noted that Australia produces only 30 graduate engineers per 100,000 people compared with Japan 82, Canada 73, the UK 63 and USA 50. Qun (1989) has likewise emphasised the connection between 'engineering education and the rise and decline of the state', suggesting that the American engineering education system which has led to the 'emergence of talented people with great creativity' has also been responsible for that nation's industrial power.

Students and graduates surveyed for the Williams Report indicated a desire for greater emphasis on the social role of the engineering profession and for development of communication skills and a creative approach to problem solving. These views have been echoed by numerous other commentators on engineering education in recent years. The Williams Report also found that engineering schools have been more responsive to changes in engineering science and equipment than to changes in engineering practice, and too little interested in the human element of technology.

Sharon Beder (1989) has argued that this tend towards greater emphasis on science and mathematics in engineering education has been partly necessitated by the complex nature of modern technology, but has also occurred because it has been seen as adding status to engineering. However, she argues that, ironically, rather than adding status to the
profession it has resulted in engineers losing their previous central role and high esteem in society.

When engineers were regarded as designers serving human needs their centrally important role in guiding human affairs was obvious. With the emphasis on science and technology and neglect of the social, political and environmental issues that shape engineering practice in the real world, the role of engineers has been perceived as belonging firmly in the technical experts box, removed from a central place in guiding the welfare of the state. Consequently engineers have lost their previous high status which flowed from this role.

Beder suggests that a further consequence of the emphasis on technical matters by the profession is that the students attracted to engineering courses tend to be those 'who enjoy math's and science and who identify themselves as being mechanically inclined' but 'are often not interested in wider social issues'. Perhaps because of 'social expectations and conditioning' few women have selected engineering as a desirable career.

Codner (1993) has suggested that if engineers are to regain the esteem in which the profession was once held, they need to re-emphasise socially responsible design and creativity as key planks of their profession. Following Beder's argument a corollary of such emphasis may be that a greater number and wider range of students would be attracted to engineering schools, including more women. Interestingly the environmental engineering degree courses attracted student with very high tertiary entrance scores and more than 50% of female students (Codner, 1993). Discussion by (Nguyen et al, 1997) with the students indicates that the perception that the degree is concerned with training for design and creative problem solving within a social sustainable setting is an important attractant. If this is so then perhaps the curriculum modifications suggested in this thesis as necessary to fulfill training for environmental responsibility, may simultaneously serve to attract greater numbers and a wider range of high quality students to engineering schools and in so doing meet a primary need identified in the Williams Report.

"Engineers can either turn to face the sun, since the sun is the basis of sustainability, or continue on the road charted as 'disquiet' by the UN Undersecretary General. A conscious choice is required, and it is needed now. Choice of the right path requires thinking about the nature and philosophy of engineering that has not been done before. Far from being beleaguered and unappreciated, engineers hold in their own hands the prospect of a new culture whose potential far exceeds the contributions of the past."

(Cortese, 1992, p. 93)
Many engineering academics have the vision. What is needed is the resolve and effort to make the change happen. Finally, all academics should check whether the sun is on their face, and if not, turn towards it.

### 6.6 Recommended direction for future engineering education

The survey results findings are consistent with other studies and reports carried out in this field. A number of issues that demand to be addressed in the following recommendations are suggested by the author for the future design of engineering education curricula:

i. There is needed a single corporate 'think tank' that combine the talents, experience and foresight of all the parties to give overall vision, planning and direction to the processes of modern engineering education and professional development, community, government, industry, professional institutions and educators.

ii. Educators and trainers in engineering education and professional development must themselves be re-equipped to deliver quality assured training and engineering sustainable education.

iii. The whole professional development and training process in engineering needs to be thoroughly reviewed with industry and graduated students to develop the formation of skills and attributes pertinent to a dynamic global market place. This means nothing less than a substantial investment in sustainable education modes of teaching and curricula in engineering.

iv. A proposal for an "infusion" model to provide parallel streams involving a four year environmental engineering education program and adapted programs in the usual specialist areas have been suggested in appendix III.
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Dear Head, Engineering Faculty

I am writing to you to ask for your co-operation in the distribution of this survey to your staff. Your staff are invited to take part in this national survey of all staff of engineering education at Australian Universities.

The purpose of this study is to analyse the current state of the integration of environmental education into engineering courses throughout Australia. The study will examine both the education of environmental engineers and the education of traditional or conventional engineers (civil, mechanical, electrical, mining and materials).

Could you please pass on a copy of this survey and ask staff to return it as soon as possible in the enclosed reply-paid envelope to:

Dr. F. Sidrak  
Faculty of Education  
University of Wollongong  
Northfields Ave  
Wollongong NSW 2522

Please be assured that the answers by your staff will be treated in the strictest confidence, and the results will not contain information which could identify individuals or individual institutions.

If your staff have any questions, concerns or queries about the survey or how to complete the questionnaire, please call on 042 213865 or e.mail Fady_Sidrak@uow.edu.au.

Many thanks and I hope that your staff will take the time to give us their opinions.

Yours faithfully

John Patterson  
Dean, Faculty of Education
FUTURE DIRECTIONS IN THE ENVIRONMENTAL EDUCATION OF ENGINEERS

You are invited to take part in this survey of all staff of engineering education by completing this questionnaire and returning it as soon as possible in the enclosed reply-paid envelop to:

All data collected will be coded so individuals and institutions cannot be identified.

Dr. F. Sidrak
Faculty of Education
University of Wollongong
Northfields Ave
Wollongong NSW 2522

Survey-Instructions

Purpose of the Survey

The environmental education of engineers is an important feature of environmentally sustainable development (ESD). The goal of this survey is to assess the level and kind of environmental education engineers are being offered in Australia, and to identify the key issues and problems facing staff who teach these courses.

Sponsors

The survey is being conducted by F. Sidrak of the University of Wollongong, Faculty of Education.

Due Date: 30th September 1998

Help Line

If you require more assistance please contact:

Dr. Fady Sidrak on 042 213865, or E-mail Fady_Sidrak@uow.edu.au

THANK YOU FOR YOUR TIME AND CO-OPERATION

Yours faithfully

Fady Sidrak
UNIVERSITY OF WOLLONGONG

FUTURE DIRECTIONS IN THE ENVIRONMENTAL EDUCATION OF ENGINEERS
Do you teach a subject which has an environmental education component within an engineering degree?

[ ] Yes  [ ] No

Section 1: Environmental issues

• To what extent should the following issues be covered in engineering degrees?

• To what extent are they taught in your degrees?

Rate each of the issues listed below on a scale of 1 to 4, where 1 = must be included, 2 = could be included, 3 = undecided, 4 = should not be included.

<table>
<thead>
<tr>
<th>Issues</th>
<th>Your rating of issues</th>
<th>Taught in degree courses offered by your department or school</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engineering for sustainable development</td>
<td></td>
<td></td>
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<tr>
<td>The ethics implicit in environmental engineering</td>
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<tr>
<td>The philosophical basis of public concern for the environment</td>
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<td></td>
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<tr>
<td>The basic principles of environmental science</td>
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</tr>
<tr>
<td>The different opinions of scientists, engineers, and the public on environmental issues</td>
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<td></td>
</tr>
</tbody>
</table>

List any other environmental issues that you think should be taught during undergraduate engineering degrees.

•
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•
•
•
•
Section 2: Environmental knowledge

- What essential environmental knowledge does an engineer need?
- To what extent are they taught in your degrees?

Rate the importance of the knowledge described below on a scale of 1 to 4, where 1 = most important, 2 = quite important, 3 = some importance, 4 = not important.

<table>
<thead>
<tr>
<th>Knowledge</th>
<th>Your rating of knowledge</th>
<th>Taught in degree courses offered by your department or school</th>
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</thead>
<tbody>
<tr>
<td>Knowledge of the environmental setting of an engineering problem</td>
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<td></td>
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<tr>
<td>Knowledge of monitoring procedures and assessment standards of environmental quality</td>
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<td></td>
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<tr>
<td>Knowledge of relevant environmental legislation and policy</td>
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<td></td>
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<td>Knowledge of environmental design and cleaner production</td>
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<td>Knowledge of environmental economic management for sustainability</td>
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<td></td>
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<td>Knowledge of environmental risk assessment and knowledge of occupational health and safety</td>
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<td>Knowledge of environmental precautionary principles</td>
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<td>Knowledge of environmental life cycle analysis</td>
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<td>Knowledge of environmental management procedures</td>
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<tr>
<td>Knowledge of the role of the engineer in the society</td>
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<td></td>
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<tr>
<td>Knowledge of the impact of engineering technology on social structure and culture</td>
<td></td>
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<tr>
<td>List any other environmental knowledge that you think that engineers should develop during their undergraduate degrees.</td>
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</tbody>
</table>

Appendix I
Section 3: Environmental attitudes, and skills

- What environmental attitudes, and skills are needed by engineers?
- To what extent are they taught in your degrees?

Rate each attitude, and skill described below on a scale of 1 to 4, where 1 = most important, 2 = quite important, 3 = some importance, 4 = not important.

<table>
<thead>
<tr>
<th>Attitudes &amp; skills</th>
<th>Your rating of attitudes &amp; skills</th>
<th>Taught in degree courses offered by your department or school</th>
</tr>
</thead>
<tbody>
<tr>
<td>A commitment to environmental sustainability</td>
<td></td>
<td>1 2 3 4 Yes No</td>
</tr>
<tr>
<td>A commitment to global responsibility</td>
<td></td>
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<tr>
<td>An appreciation of the complexity of the biosphere</td>
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<tr>
<td>An appreciation of uncertainty, complexity and change</td>
<td></td>
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<tr>
<td>The development of a systems approach to design and management</td>
<td></td>
<td></td>
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<tr>
<td>The development of skills in quantitative and qualitative assessment</td>
<td></td>
<td></td>
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<tr>
<td>The development of skills needed to deal with complexity</td>
<td></td>
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<tr>
<td>The development of skills needed to take a long term view of projects</td>
<td></td>
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<tr>
<td>The development of skills needed to apply criteria against which to assess proposals</td>
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<tr>
<td>The development of skills needed to apply the guiding principles from ethical practice</td>
<td></td>
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<tr>
<td>The development of skills needed to relate and understand environmental issues, beyond an engineer's immediate specialisation</td>
<td>1 2 3 4 Yes No</td>
<td></td>
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</tbody>
</table>

List any other environmental attitudes or skills that you think that engineers should developed during their undergraduate degrees.

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Section 4: Environmental topics

- To what extent should the topics listed in the table below be developed in existing environmental education within engineering degrees?

- To what extent are they taught in your degrees?

Rate the importance of each environmental topic on a scale of 1 to 4, where 1 = most important, 2 = quite important, 3 = some importance, 4 = not important.

<table>
<thead>
<tr>
<th>Topics</th>
<th>Your rating of topics</th>
<th>Taught in degree courses offered by your department or school</th>
</tr>
</thead>
<tbody>
<tr>
<td>System approaches to environmental problems</td>
<td>1 2 3 4</td>
<td>Yes No</td>
</tr>
<tr>
<td>Problem solving approaches</td>
<td></td>
<td></td>
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<tr>
<td>Government environmental policy and legislation</td>
<td></td>
<td></td>
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<tr>
<td>Communication with other professionals</td>
<td></td>
<td></td>
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<tr>
<td>Local, regional and global environmental problems</td>
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<tr>
<td>Environmental economics</td>
<td></td>
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<tr>
<td>Ecological understanding</td>
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<tr>
<td>Appreciation of a range of different value systems in understanding environmental issues, social issues and policy</td>
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<tr>
<td>Environmental law and policy issues</td>
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<tr>
<td>Sustainable development concepts</td>
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</tbody>
</table>

List any other environmental topics that you think that engineers should developed during their undergraduate degrees.

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Appendix I 173
## Section 5: Goal of engineering degrees

- To what extent should the goals listed in the table below be developed in existing environmental education within engineering degrees?

- To what extent are they taught in your degrees?

Rate the importance of each goal of engineering degrees on a scale of 1 to 4, where 1 is "very important", 2 = quite important, 3 = some importance, 4 = not important.

<table>
<thead>
<tr>
<th>Goals</th>
<th>Your rating of goals</th>
<th>Taught in degree courses offered by your department or school</th>
</tr>
</thead>
<tbody>
<tr>
<td>To produce engineers (IEAust Category 2-4)</td>
<td></td>
<td></td>
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<tr>
<td>To underpin engineering knowledge (IEAust Category 1)</td>
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<tr>
<td>To develop breadth of issues (IEAust Category 2)</td>
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<tr>
<td>To integrate concepts (IEAust Category 3)</td>
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<tr>
<td>To develop professional responsibility (IEAust Category 6)</td>
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<tr>
<td>To develop management skills (IEAust Category 5)</td>
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<tr>
<td>To develop policy (IEAust Category 5)</td>
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<tr>
<td>To develop communication skills (IEAust Category 4)</td>
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<td></td>
</tr>
<tr>
<td>To enhance communication skills (IEAust Category 4)</td>
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<td></td>
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<tr>
<td>List any other goals that you think that should included in</td>
<td></td>
<td></td>
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<tr>
<td>undergraduate degrees in engineering.</td>
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</tbody>
</table>

List any other goals that you think that should included in undergraduate degrees in engineering.

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Appendix I

174
**Section 6: Factors influence on demand for graduates**

- What factors affect the demand for environmental education in engineering degrees?

Rate each factor that may influence demand on a scale of 1 to 4, where 1 is “very important”, 2 = quite important, 3 = some importance, 4 = not important.

<table>
<thead>
<tr>
<th>Factors</th>
<th>Your rating of factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Lack of government policy</td>
<td></td>
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<tr>
<td>Lack of political commitment to environmental education of engineers</td>
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<tr>
<td>Lack of school or department response to policy</td>
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<tr>
<td>Lack of understanding of environment issues in engineering disciplines</td>
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<tr>
<td>Lack of qualified lecturers/teachers</td>
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<tr>
<td>Lack of funds to employ lecturers/teachers</td>
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<tr>
<td>Lack of funds to develop teaching materials</td>
<td></td>
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<tr>
<td>Resistance in engineering disciplines to environmental education</td>
<td></td>
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<tr>
<td>Disciplinary/faculty barriers to cooperation with other environmental educators</td>
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<tr>
<td>Lack of room in curriculum</td>
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<tr>
<td>List any other environmental factors that you think may affect the demand.</td>
<td></td>
</tr>
</tbody>
</table>

Appendix I 175
Section 7: Syllabus or courses review

7.1 How often are there reviews of curricula in your school or department?

[ ] every 1 to 3 years  [ ] every 4 to 6 years  [ ] never

7.2 What were the main recommendations of your most recent review?
[Attached document if this inconvenient]

7.3 Do you believe the existing degrees in environmental engineering offered by your school or department are adequate for the environmental and developmental needs of societies?

Strongly agree [ ]  Agree [ ]  Unsure [ ]  Disagree [ ]  Strongly disagree [ ]

7.4 Why/why not?

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### Section 8: Proposed Objectives

- What do you think should be the objectives of environmental education within an engineering degree?

- To what extent are they taught in your degrees?

Rate the importance of each objective listed below on a scale of 1 to 4, where 1 is "very important", 2 = quite important, 3 = some importance, 4 = not important.

<table>
<thead>
<tr>
<th>Objectives</th>
<th>Your rating of the importance of the objective</th>
<th>Taught in degree courses offered by your department or school</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<tr>
<td>Develop core engineering skills</td>
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<tr>
<td>Develop a satisfactory scientific base for understanding environmental issues</td>
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<tr>
<td>Provide a global environmental perspective</td>
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<td></td>
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<tr>
<td>Develop an understanding of how to integrate environmental criteria</td>
<td></td>
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<tr>
<td>Develop an understanding of assessment techniques of the environmental impacts of modern technology</td>
<td></td>
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<tr>
<td>Provide an understanding of the development of environmental policy and its implementation</td>
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<tr>
<td>Provide an understanding of techniques for formulating and implementing community consultation programs</td>
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<tr>
<td>Develop the ability to communicate environmental issues objectively and coherently to different audiences</td>
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<tr>
<td>List any other environmental objectives that you think that engineers should develop during their undergraduate degrees.</td>
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</tbody>
</table>

Appendix I 177
Section 9: Communication skills

- Which specific communication skills do you think should be developed throughout engineering degrees?
- To what extent are they taught in your degrees?

Rate the importance of each communication skill on a scale of 1 to 4, where 1 is "very important", 2 = quite important, 3 = some importance, 4 = not important.

<table>
<thead>
<tr>
<th>Communication</th>
<th>Your rating of communication skill</th>
<th>Taught in degree courses offered by your department or school</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 2 3 4</td>
<td>Yes No</td>
</tr>
<tr>
<td>Reading letters, faxes, memos</td>
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<td></td>
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<tr>
<td>Writing letters, faxes, memos</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reading/using drawings</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reading trade literature</td>
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<td></td>
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<tr>
<td>Reading minutes of meetings</td>
<td></td>
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<tr>
<td>Reading technical reports</td>
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<tr>
<td>Reading/Evaluating commercial documents</td>
<td></td>
<td></td>
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<tr>
<td>Reading management reports</td>
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<tr>
<td>Writing technical reports</td>
<td></td>
<td></td>
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<tr>
<td>Filing and retrieving documentation</td>
<td></td>
<td></td>
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<tr>
<td>List any other communication skills that you think</td>
<td>Taught in degree courses offered by your department or school</td>
<td></td>
</tr>
<tr>
<td>that engineers should developed during their</td>
<td>Yes No</td>
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<tr>
<td>undergraduate degrees.</td>
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Section 10: Ethics

- What level of importance should be given to the development of a sustainability ethic by students?

Rate the importance of this ethical development for students on a scale of 1 to 4, where 1 is “very important”, 2 = quite important, 3 = some importance 4 = not important.

<table>
<thead>
<tr>
<th>Your rating of ethical development for students</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
</tr>
</tbody>
</table>

- What level of importance is actually given to the development of a sustainability ethic in your degrees?

<table>
<thead>
<tr>
<th>Actual rating in your department or school of ethical development for students</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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</tbody>
</table>

Thank you for your cooperation-if you have any questions please contact us at Faculty of Education, University of Wollongong, Wollongong, NSW 2522, Australia.

Option Information

If you are willing to be contacted to further clarify any of your responses, could you please supply the information below. This information will be strictly confidential.

Name...............................................................................

Phone...............................................................................

Fax..................................................................................

E. mail.............................................................................
## Appendix II

### Crosstabulation Data

<table>
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Appendix II
| Appendix II | 181 |
Abbreviations

M  Mean
%  Percentage
L  Lecturer
S. L.  Senior Lecturer
A. Prof.  Associate Professor
Prof.  Professor
A. D.  Assistant Dean
T  Total
Q  Question No.
R  Rank
S 1, 2, 3, 4, 5, 6, 7, 8, 9, 10  Sections No.
Proposed Environmental Systems Engineering Major in the BE

1. Rationale

Community understanding of what constitutes "wealth" is evolving beyond that measured by consumption based economic indicators such as gross domestic product. Over the next several decades greater and greater value will be placed on what has been termed "natural" and "social" capital. The new imperative is sustainable development. Technology will play a part in bringing about this goal through remediation of compromised sites and the development of technologies that support much greater energy and resource efficiencies in all sectors of the economy. The solutions adopted will involve innovations from many different interest groups in society; compromises will need to be negotiated between interest groups based on a clear understanding of the technological options and the use of a broadly based systems perspective and the long term analysis of costs and benefits. Engineers will play an important role in this process. They will need to understand the issues, be able to effectively use appropriate analytical tools, be able to participate in interdisciplinary teams generating possible solutions and be able to communicate their findings to a variety of audiences.

The Environmental Systems Engineering major begins by giving students a sound foundation in environmental sciences and the related engineering science areas needed to understand the challenges to the health of water, air and soil systems that arise from current community practices and industrial processes. Subsequent subjects develop tools for modelling environmental systems in one or more of the three domains and investigate strategies for addressing the problems through techniques such as environmental auditing, waste management, clean manufacturing, life cycle analysis and other methods. The major provides an opportunity for students to focus on one of three sectors of the economy in the last stage of the course: transport, energy or water. For added breath, the major can be combined with sub-majors in electrical, mechanical, computer systems or telecommunications engineering. To add further skills in environmental design and management Electives may be taken from subjects offered in the Environmental Engineering Management, the Energy Planning and Policy Graduate Program, or the groundwater Management program.
2. Contribution to graduate attributes

• Professional formation

Graduates will be well grounded in the fundamentals of the physical sciences, mathematics, and environmental systems engineering, so that they will have the flexibility to work in new discipline areas. They will be able to communicate effectively with professionals working in other environmental disciplines. The field of practice will develop many of the technical skills needed to work as an environmental engineer. These skills will include the modelling, analysis and designing environmental systems for specific purposes.

This major when combined with other fields of practice subjects or with subjects from the Master of Environmental Engineering and other graduate programs will enable graduates to engineer solutions for environmental problems in a number of discipline areas.

Besides these technical skills, the field of practice will provide further opportunity for development of the broader graduate attributes such as ability to work in teams, communications skills, reflection, and ethical conduct. This will be achieved by integrating into the subjects team work based reports, fieldwork, frequent opportunities to make written and oral presentations, where there will be the opportunity to reflect on many aspects of the profession, including ethical issues.

• Academic development

The field of practice will develop academic skills such as problem posing and solving, critical reading, recollection of important facts, research skills, comprehension, written and oral presentation skills, and ability to carry out complex analysis. These skills will be achieved by the student's perception of the professionalism of the lecturing staff and the critical evaluation of assignments and presentations. Their performance will be measured also in oral and written examinations.

• Personal development

Using the sustainability theme as the framework of the course, students will gain an understanding of engineering as part of an inter-disciplinary rational that affects the future of the world's environment.
Throughout the course, the self-confidence of the students will grow as they gradually increase their competencies. They will become more reflective, through journal writing and the development of a personal portfolio. Finally the students will develop leadership qualities and intercommunication skills because of the many team-based activities.

3. Subject descriptions

Key to abbreviations used in subject descriptions

The following abbreviations have been used to indicate where a subject forms a prescribed or recommended part of a major or course.

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>CE</td>
<td>Civil Engineering Major</td>
</tr>
<tr>
<td>CEE</td>
<td>Civil and Environmental Engineering Major</td>
</tr>
<tr>
<td>CSE</td>
<td>Computer Systems Engineering Major</td>
</tr>
<tr>
<td>ESE</td>
<td>Environmental Systems Engineering</td>
</tr>
<tr>
<td>EE</td>
<td>Electrical Engineering Major</td>
</tr>
<tr>
<td>ME</td>
<td>Mechanical Engineering Major</td>
</tr>
<tr>
<td>SE</td>
<td>Software Engineering</td>
</tr>
<tr>
<td>TE</td>
<td>Telecommunications Engineering Major</td>
</tr>
<tr>
<td>BEBA</td>
<td>Bachelor of Engineering, Bachelor of Arts in International Studies</td>
</tr>
<tr>
<td>BEBBus</td>
<td>Bachelor of Engineering, Bachelor of Business</td>
</tr>
<tr>
<td>BScBE</td>
<td>Bachelor of Science, Bachelor of Engineering</td>
</tr>
<tr>
<td>BT</td>
<td>Bachelor of Technology</td>
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</tbody>
</table>

4. Environmental Systems Engineering Major

Community understanding of what constitutes ‘wealth’ is evolving beyond that measured by consumption-based economic indicators such as gross domestic product. Technology will play a part in bringing about this goal through remediation of compromised sites and the development of technologies that support much greater energy and resource efficiencies in all sectors of the economy. The solutions adopted will involve innovations from many different interest groups in society; compromises will need to be negotiated between interest groups, based on a clear understanding of the technological options and the use of a broadly based systems perspective and the long term analysis of costs and benefits. Engineers will play an important role in this process. They will need to understand the issues, be able to effectively use appropriate
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5. Bachelor of Engineering

Abbreviation: BE

5.1 Sub-majors

The author has defined a large number of sub-majors for students who wish to use their elective components to undertake a coherent program of study in a discipline complementary to their major. Some sub-majors are available to all students, others only to students in specific majors. Each sub-major is defined as a selection of any four subjects drawn from a larger set – typically six to eight. The subjects included in a sub-major set could consist of one or more of the following types: fields-of-practice subjects from another major, graduate engineering subjects, and subjects offered by other Faculties.
The sub-majors currently available are:

<table>
<thead>
<tr>
<th>Sub-major</th>
<th>Available to students majoring in:</th>
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</thead>
<tbody>
<tr>
<td>Biomedical Technology</td>
<td>Computer Systems Engineering, Mechanical, Telecom</td>
</tr>
<tr>
<td>Electrical, Business</td>
<td>All</td>
</tr>
<tr>
<td>Chemical Technology</td>
<td>Mechanical, Environmental Systems</td>
</tr>
<tr>
<td>Civil Engineering</td>
<td>All but Civil, Civil and Environmental</td>
</tr>
<tr>
<td>Computer Control and Instrumentation</td>
<td>Electrical</td>
</tr>
<tr>
<td>Computer Networking</td>
<td>All</td>
</tr>
<tr>
<td>Computing Science</td>
<td>All but Computer Systems Engineering</td>
</tr>
<tr>
<td>Construction and Management</td>
<td>Civil, Civil and Environmental</td>
</tr>
<tr>
<td>Energy Systems</td>
<td>Electrical, Mechanical</td>
</tr>
<tr>
<td>Engineering Management</td>
<td>All</td>
</tr>
<tr>
<td>Environmental Engineering</td>
<td>All but Civil and Environmental, and Environmental Systems</td>
</tr>
<tr>
<td>Information Systems Engineering</td>
<td>All</td>
</tr>
<tr>
<td>Internet Software Development</td>
<td>Computer Systems Engineering, Software Engineering</td>
</tr>
<tr>
<td>Land and Water</td>
<td>Civil</td>
</tr>
<tr>
<td>Manufacturing Systems</td>
<td>Mechanical, Electrical</td>
</tr>
<tr>
<td>Materials</td>
<td>Civil, Civil and Environmental</td>
</tr>
<tr>
<td>Mathematics</td>
<td>All</td>
</tr>
<tr>
<td>Mechanical Design</td>
<td>Mechanical</td>
</tr>
<tr>
<td>Mechanical Engineering</td>
<td>All but Mechanical</td>
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<tr>
<td>Mechatronics</td>
<td>Electrical, Mechanical</td>
</tr>
<tr>
<td>Operations Research</td>
<td>All</td>
</tr>
<tr>
<td>Software Engineering</td>
<td>All but Software Engineering</td>
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<tr>
<td>Statistics</td>
<td>All</td>
</tr>
<tr>
<td>Structures</td>
<td>Civil</td>
</tr>
<tr>
<td>Telecommunications Engineering</td>
<td>Electrical, Computer Systems Engineering</td>
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Appendix III 187
<table>
<thead>
<tr>
<th>Semester</th>
<th>Courses</th>
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</table>
| Sem 1    | Engineering for Sustainability (core)  
Chemistry and Materials Science (fields of practice)  
Biology and Ecology (fields practice)  
Introduction to Environmental Engineering (fields of practice) |
| Sem 2    | Informatics (core)  
Mathematical Modelling 1 (core)  
Physical Modelling (core)  
Environmental Physical Chemistry (fields of practice) |
| Sem 3    | Engineering Communication (core)  
Mathematical Modelling 2 (core)  
Fluid Mechanics (fields of practice)  
Environmental Monitoring (fields of practice) |
| Sem 4    | Uncertainties and Risks in Engineering (core)  
Thermodynamics (fields of practice)  
Hydraulics and Hydrology (fields of practice)  
Soil and Landscape Systems (fields of practice) |
| Sem 5    | Engineering Economics and Finance (core)  
Air and Noise Pollution (fields of practice)  
Environmental Biotechnology and Ecotoxicology (fields of practice)  
Environmental Geotechnics (fields of practice) |
| Sem 6    | Engineering Management (core)  
Life Cycle Analysis (fields of practice)  
Environmental Systems Modelling (fields of practice)  
Elective |
| Sem 7    | Technology Assessment (core)  
Environmental Auditing (fields of practice)  
Elective  
Elective |
| Sem 6    | Project  
Sector Specific Studies in Transport Energy or Water (fields of practice)  
Elective  
Elective |
6. Subject descriptions

Engineering for Sustainability

CE, CEE, CSE, ESE, EE, ME, SE, TE, BEBA, BEBBus, BScBE
6cp
Core

Upon completion of this subject, students should be able to demonstrate development in the following areas:

- orientation to university study;
- ability to read critically and write appropriately in a variety of academic contexts;
- appreciation of the social and historical contexts of engineering;
- awareness of different definitions of 'progress';
- awareness of what is 'professionalism';
- appreciation of the role of codes of ethics; and
- appreciation of the principles of sustainability.

This subject takes students on a journey into the past, present and future of engineering and its relationship to society and the environment. They will choose one of several module groups based around broad engineering-related themes.

Within these modules, students will be examining the contributions made by engineers in their respective areas, how they were received by and benefited different groups in society, and what impact they had on the environment. Current and historical case studies from our local communities as well as from other parts of the world will be used to illustrate the different ways in which technologies have evolved and have been valued.

The subject is taught by an interdisciplinary team who will present lectures, and facilitate interactive workshops. Assessment includes individual reflective writing, case study reports, and team-based poster presentation. In each of these assessment tasks, students are assessed both for their learning of key content material and academic skills such as critical reading and analysis, and academic writing and presentation.
Chemistry and Materials Science

6cp

The objectives of the subject are to develop: an understanding of why engineers require a fundamental understanding of chemistry and materials; a solid science foundation for further engineering studies; an understanding of the fundamentals of chemistry and materials terminology and nomenclature in order to facilitate the working relationship of engineers, chemists and materials scientists; an ability to identify and solve chemical projects in engineering projects; and an ability to relate the properties of engineering materials in environmental and in manufacturing fields.

Topics include: chemical bonding of materials - electronic structure of materials, fundamental bonding concepts, chemical reactions; materials science and engineering - classification of materials, structure property relationship, mechanical properties, ferrous and non-ferrous alloys, engineering ceramics, polymers and composites, materials degradation and materials selection; industrial organic chemistry - hydrocarbons, spontaneous reactions, electrochemical cells, electrolysis, electroplating industrial processes, corrosion theory, application and protection.

Biology and Ecology

6cp; 6hpw

The principals of biology and ecology for students majoring in Environmental Engineering and other fields. Structure and function of cells, cell divisions and the role of genetic material in cell function; biodiversity - the classification, distinguishing characteristics of plants, animals and microorganisms and their economic, medical and ecological importance; the physiology of higher plants and mammals and the effects of environmental pollution and disturbance; the principals of population and community ecology, the structure and function of aquatic and terrestrial ecosystems; the effects and management of human impacts on natural ecosystems.
Introduction to Environmental Engineering

CEE, ESE, BEBA

6cp

Fields of practice: Environmental Engineering Program

The objectives of this subject are: to introduce students to key concepts of environmental science and engineering, and to the social, legislative and political context of the work of environmental engineers; to develop their understanding of the consequences of humans interacting with their environment; to enable them to answer questions such as What is 'pollution'? and What skills are needed for the responsible practice of environmental engineering? The following material is examined and integrated:

The work of environmental engineers - local and global environmental Projects and their implications for engineers; the emergence of environmental engineering as a separate discipline; issues addressed by engineers who regard themselves as environmental engineers in Australia; career paths; interactions between environmental engineers and other professions, occupations and groups; community attitudes towards engineers and the social and professional implications of these attitudes for their work; the IEAust Code of Ethics and policies on the environment, heritage and sustainability; journals and other sources of information on environmental engineering; an introduction to environmental management systems and auditing.

The social environment - the social construction of 'environment'; environmental ethics; an introduction to environmentalism, especially in Australia; aims and strategies of Australian non-governmental environmental organisations and community action groups. The political and legislative environment - how environmental policy and decisions are made; the nature of environmental disputes, and their resolution; environmental legislation and environmental planning.

The natural environment - the atmosphere, hydrosphere and geosphere; the science of the atmosphere and hydrosphere; the concept of biogeochemical cycles in the context of environmental engineering; an introduction to climate, geomorphology, and soil and vegetation associations; methods used to monitor the environment, and geographical information systems. Consequences of humans interacting with their environment - the environmental impacts of poorly planned urbanisation, industrialisation, and other
forms of development; the sources, causes, and effects of air, noise, water and soil pollution; an introduction to the mitigation and abatement of these impacts.

Informatics

CE, CEE, CSE, ESE, EE, ME, SE, TE, BEBA, BEBBus, BScBE
6cp
Core

The objectives of this subject are: to develop a deep understanding of the types of engineering Projects which can benefit from the use of information and computational tools; to identify these benefits, the types of tools and their appropriateness, strengths and limitations; to develop an understanding of the application of, and specific skills in applying, informatics tools to engineering Projects (and in particular in the areas of utilising information, oral and written communication, teamwork, resource management, design processes); and to develop maturity with respect to critical thinking and professional ethics.

Topics include: consideration of issues related informatics tools and categories of informatics tools, types of Projects which can benefit from these tools, benefits of using tools, limitation of tools, relevance of tools to different types of Projects; consideration of issues related to using tools to identify, structure, conceptualise, visualise, articulate, and reason about engineering Projects; consideration of issues related to how tools relate to the culture of engineering, engineering ethics, and critical thinking; specific skills in computing programming fundamentals, and a specific programming language; skills in using operating systems, written and oral communication software, spreadsheets, Internet tools, mathematical modelling tools, databases, teamwork tools, and Project management tools.

Mathematical Modelling 1

6cp

This subject will develop all the standard ideas of single variable calculus, but will use specific physical models to provide a context for the mathematical concepts. The material will appear for different purposes and in a different order to standard
presentations. There are ties to experiments done in basic physics subjects to further reinforce the relevance of the mathematical concepts.

Physical Modelling

CE, CEE, CSE, ESE, EE, ME, SE, TE, BEBA BEBBus
6cp;
Core

The objectives of this subject are to provide students with: a conceptual basis in mechanics, thermal physics, waves and optics, electric and magnetic fields; Project solving skills through practice in selected Projects; an appreciation of the role of modelling, and hence mathematics, in understanding and describing the natural world; the basic techniques of physical measurement, data analysis and verification of models; technical communication skills; an understanding of nature through its natural components, with an emphasis on vector methods and modes (including frames of reference, coordinate systems and orthogonality); an appreciation of the nature of physics as a professional discipline of great importance to engineering innovation; an ability to use physical concepts in a mathematical formulation and hence be able to apply those concepts to engineering Projects.

Environmental Physical Chemistry

ESE
6cp;
Fields of practice: Environmental Engineering Program

This subject is designed to provide students with a sound knowledge of the underlying physical chemistry principles of chemical thermodynamics and reaction kinetics, in the study of environmental systems engineering. A sound knowledge of these twin pillars of physical chemistry is extremely important for numerous professional environmental engineering activities that include process design for waste treatment, as well as fate and transport modelling. The bedrock of environmental engineering is a sound knowledge of chemical thermodynamics and reaction kinetics. Unfortunately, these topics are not formally addressed in most environmental engineering curricula.

During the early stages of the development of environmental engineering, the emphasis was on air and water quality, hence traditional courses in environmental engineering
focussed on the basic chemistry of water analysis, and to some extent atmospheric processes. Over the last few decades a change in both the emphasis and content of environmental engineering has occurred, due to its interdisciplinary nature.

Engineering Communication

CE, CEE, CSE, ESE, EE, ME, SE, TE, BEBA, BEBBus, BScBE
6cp;
Core

On completion of this subject students should be able to: understand basic principles and theories of human communication; research within the various discipline areas that inform the study of communication; write competently in a number of different genres; perform competently in a variety of oral communication situations; understand basic principles and practices of graphic communication; demonstrate their ability to express engineering concepts through graphical communication; demonstrate their ability to 'converse' mathematically; lead and participate in group processes; appreciate the central role of communication in engineering practice.

Topics include: principles and theories of communication; communication in practice; the processes of communication; and communication technology.

Mathematical Modelling 2

6cp;

This subject will develop concepts of linear algebra and multivariable calculus, but using motivational examples more than is usual. Such examples include production Projects, overdamped motion, the concepts of work and rotational motion and various concepts such as centres of mass and moments of inertia. The concepts of probability will be introduced and motivated by focusing on the determination of the reliability of a system of components, such as - electric circuit for fire detection, a suspension bridge or an engine's lubrication system. Subject material will include variance, skewness and kurtosis, probability distributions, conditional probability and bivariate probability.
Fluid Mechanics

CE, CEE, ME, BEBA BEBBus
6cp;
Fields of practice: Mechanical Engineering Program

The objectives of this subject are to enable students to: understand key concepts and fundamental principles, together with the assumptions made in their development, pertaining to fluid behaviour, both in static and flowing conditions; deal effectively with practical engineering situations, including the analysis and design of engineering systems and devices involving fluid flow; and engage in further specialised study or research.

Topics include: fluid properties and statics; conservation laws: of mass, momentum and energy; dimensional analysis and similitude; flow in pipes; external flow - lift and drag; potential flow; boundary layers; flow measurements; environmental hydraulics.

Environmental Monitoring

ESE, BEBA, BEBBus
6cp;
Fields of practice: Electrical Engineering Program

This subject aims to provide students with an understanding of the possibilities and limitations of methods used for environment monitoring; and to develop the ability to select, use and interpret the results of local and remote sensing equipment to monitor the quality of the environment for some specific applications.

Topics include: physical quantities and qualities of the environment monitored using suitable instrumentation, referring particularly to water, air, noise and soil pollution and degradation; methods and equipment for environment measurement and monitoring; local sensing and remote data transmission; remote sensing using satellites and aerial surveys; access to information on the environment.

Other Topics include: fundamentals of Data Acquisition Systems; physical principles and characteristics of local sensors for temperature, pressure, flow rate, radiation, chemical composition and pollution of gases, liquids and soil; biosensors for indoor and outdoor pollutants; meteorological monitoring; signal conditioning and processing.
of sensor signals; analog to digital conversion and microcomputer control of DAS; remote data transmission, telemetry; display, recording, processing and analysis of data; and software for data acquisition, data logging and data analysis. It also covers: the principles of remote sensing; electromagnetic radiation; multispectral and thermal photographic sensing; image resolution, processing and interpretation; active microwave sensing; remote sensing of terrestrial environment and geophysical parameters; monitoring of agricultural, forest and urban land usage and cover; and global remote sensing.

Uncertainties and Risks in Engineering

CE, CEE, CSE, ESE, EE, ME, SE, TE, BEBA, BEBBus, BScBE
6cp;
Core

The objectives of this subject are: to develop in students a critical understanding of ideas concerning decision-making under risk, uncertainty, ignorance and indeterminacy (and an appreciation that each person and group has knowledge, attitudes and beliefs about risk and uncertainty which, to the individual or group, are 'rational'); to explore the contexts in which experts, including professional engineers, manipulate Projects involving risk and uncertainty; to develop a critical appreciation of the uncertainties and subjectivities inherent in modelling; and to equip students with the ability to select and apply appropriate statistical tools, to acquire additional statistical competencies, and to understand their strengths and limitations.

Topics include: Decision making under risk, uncertainty, ignorance or indeterminacy - history of decision making under risk, uncertainty, etc.; cultural approaches to risk and uncertainty (approaches which emphasise the plurality of rationalities); the modern dependence on or fascination with quantification; historical origins of statistics and risk analysis; new approaches to negotiating risk and uncertainty decisions: the primacy of open process, trust, and valuing contextual knowledge over quantitative risk estimates; the sociology of knowledge; case studies concerning, for example, Chernobyl, lawyers' approaches to knowledge, and probabilistic knowledge; communicating and negotiating uncertainty and risk. Formal definitions of risk, uncertainty, indeterminacy and ignorance - connections to risk management and to sustainability, especially the Precautionary Principle; connections to communication, safety, reliability, quality, investment risk, measurement, and system performance evaluation; sources of errors; limitations of models as predictive tools; risk transfer, risk modification, and risk
avoidance. The role of formal methods of handling risk and uncertainty - standards, codes, and expert or professional knowledge in resolving risk or uncertainty, particularly in engineering and related professions; how models are constructed and used as the basis for codes and standards; examples and connections to the fields of practice/programs; the complexity of engineering decisions and the reductionist approach to classifying Projects; ensuring predictability, quality and reliability in the face of the random perturbations and uncertainties inherent in systems. Techniques for modelling and analysing uncertainties and risks - in order to be able to examine some hypotheses about risk and uncertainty, appreciation of the process of and mastery of some of the skills for modelling and analysis will be developed, including: different classifications of mathematical models and modelling methods, e.g. stochastic, deterministic, mixed stochastic-deterministic, parameteric, black box, simulation; linear, nonlinear, lumped parameter, distributed parameter; static, dynamic; regression and correlation analysis; choice of variables and relationships to model; sources of uncertainty propagation in models, e.g. measurement uncertainties, propagation of computational errors, system noise and disturbances, unmodelled variables, non-quantifiable variables and effects; measures of certainty and uncertainty in models, e.g. robustness, confidence intervals, statistical inference based on hypothesis testing; mechanisms for minimising effects of uncertainties in models and systems, e.g. feedback, filters, and redundancy; model verification e.g. tests of goodness of fit; model validation, e.g. statistical forecasting; how decisions are made under uncertainty; different approaches to documenting and communicating the results of statistical modelling and decision making.

Thermodynamics

ME, BEBA BEBBus
6cp,
Fields of practice: Mechanical Engineering Program

The objectives of this subject are to: develop a fundamental understanding of applied thermodynamics in an engineering perspective; use thermodynamics effectively in the practice of engineering; lay the groundwork for subsequent studies in the fields related to energy systems; and increase an awareness and emphasis on energy resources and environmental issues.

Topics include: thermodynamic properties of pure substances; compressible flow; work and heat; the first law of thermodynamics; applications to closed systems; applications
to open systems; the second law of thermodynamics; irreversibility; entropy; vapor power cycles; Rankine cycle and steam engines; refrigeration cycle; air standard power cycles; Brayton cycle and gas turbine engines; Otto cycle and spark ignition engines; diesel cycle and compression ignition engines.

Hydraulics and Hydrology

CE, CEE, BEBA, BEBBus
6cp,
Fields of practice: Civil Engineering

The objective of this subject is to give students a knowledge of open channel hydraulics and hydrology, leading to understanding of the scientific foundations and basic principles of these fields, and the ability to apply hydraulic and hydrological methods to engineering applications in an integrated way. Knowledge of fluid mechanics will be consolidated and Project-solving skills in dealing with water engineering tasks will be acquired.

Topics include: open channel hydraulics - types of flow (e.g. steady, uniform), friction equations, rapidly-varied flow, continuity, energy and momentum conservation, gradually-varied flow, water surface profiles, software packages, hydraulic structures (channel appurtenances, culverts, bridge waterways); hydrology - the hydrological cycle, water balances, meteorology and climatology, data collection, statistics, hydrological models, design rainfalls, rainfall-runoff processes, flood estimation models and procedures, software packages, yield analysis, groundwater, environmental hydrology; and integration of hydraulics and hydrology case studies.

Soil and Landscape Systems

ESE, BEBA, BEBBus
6cp;
Fields of practice: Environmental Engineering Program

The objective of this subject is to give a broad-based introduction to the geo-sciences. These sciences provide fundamental inputs to the analysis of environmental Projects associated with soil and rock. The subject is broken into three components - geology, solid engineering and soil science. Each is taught by a different lecturer in order to
familiarise students with the subject matter and terminology of the three disciplines. At the completion of the course students should be familiar with the natural processes occurring on the surface of the earth; be able to communicate with geologists, earth scientists and others involved in studying the ground and be aware of the importance of inter-disciplinary involvement; understand those aspects of soil and rock behaviour which have an important bearing on environmental impact; be able consider the broad range of inputs necessary in understanding the interaction between soil and human activities in the field of environmental engineering; and have a solid basis for further study in the field.

Topics include: geological fundamentals - soil/rock cycle, rock classification and composition, structure of rock, weathering, properties of rock, hydrogeology; an introduction to soil engineering - nature of soil, classification, soil mechanics, state of stress in soil, groundwater and seepage, permeability; soil sciences - geomorphology, soil formation and landforms, soil chemistry, soil surveying and soil inputs in environmental impact studies.

Engineering Economics and Finance

CE, CEE, CSE, ESE, EE, ME, SE, TE, BEBA, BScBE
6cp
Core

The objectives are for students to be able to use an understanding of engineering culture to develop an understanding of the relationship between economics and finance and engineering; to gain a working knowledge of macro and micro economic theories in the context of engineering practice, ethics and sustainability; to acquire skills in determining the appropriate use and limitations of various economic and financial models and techniques used to define/manage/analyse engineering activities; to develop competence in identifying and working through the economic and financial aspects of an engineering Project/case study; to become aware of the impact of various economic and financial models and techniques on the social and technical dimensions of engineering activity; to integrate economic and financial understanding and fields of practice specialist knowledge in Project-based/case study work.

Topics include: a basic understanding of macro economics, micro economics and environmental economics; awareness of the philosophies underpinning economics, and terms and methods used by economists and accountants; analysis of engineering
economic models including cost-benefit analysis, multiple-objective analysis etc; skills in assessing and using accounting and financial concepts especially in context of small business but including awareness of management accounting.

Air and Noise Pollution

ESE, BEBA BEBBus
6cp;

The objective of this subject is to enable students to understand the key concepts and fundamental principles involved in the assessment of air and noise pollution and in dealing with the associated Projects.

The air pollution component of this subject draws on material in preceding subjects on chemistry and physical and mathematical modelling, to deal with the origins and extent of air pollution Projects.

The noise pollution component introduces the student to the two main areas of noise pollution, namely: occupational noise and environmental noise. The legislation and policing bodies pertaining to these are also discussed. The noise component is presented in an applied manner with an emphasis on the measurement of noise pollution in its varied forms with a field experiment. Several case studies on noise pollution and assessment will be reviewed.

Environmental Biotechnology and Ecotoxicology

ESE, BEBA, BEBBus
6cp;

Fields of practice: Environmental Engineering Program

The role of biotechnology and ecotoxicology in environmental systems and management has long been recognized. This subject includes the following topics:

Introduction to biotechnology and ecotoxicology in environmental management; biological systems and their applications in domestic and trade waste management with an emphasis on energy production; principles of environmental bioremediation and bioaugmentation using natural and genetically modified organics and their application in
oil spills and chemically contaminated sites; genetically engineered micro-organisms in hazardous and toxic waste management; role of environmental biotechnology in the air quality improvement and the prevention of green house effect and ozone depletion; engineered and natural microorganisms in cleaner production with case studies on paper, mining and dairy industries, biosensors in environmental monitoring.

Students will explore toxic substances in aquatic, atmospheric and terrestrial environments, and the prediction of species response to pollution stress. Studies will include a look at organisms as indicators of environmental conditions and ecosystem approaches to pollution effects.

Environmental Geotechnics

ESE, BEBA, BEBBus
6cp;
Fields of practice: Environmental Engineering Program

The environmental status of soil for engineering purposes has become a major issue with the increasing urbanisation of city hinterlands and coastal plains which were formerly rural areas. The object of this subject is to introduce students to the identification, assessment and management of the development of such areas that in many instances are underlain by soils with specific physical and chemical properties. These soils include acid sulfate soil, contaminated soil and sodic soil. The subject will also address Projects such as urban soil salinity. The students will be made aware of the appropriate legislation and planning controls which provide guidelines for development and management of such areas. Other topics that are an integral part of this subject include groundwater contamination and transport and sediment and erosion control. At the completion of the course students should be able to identify these soils and be able to communicate with ecologists, earth scientists and hydrogeologists so that best management practice can be achieved.
Engineering Management

BT
6cp;

This subject provides a background in classical management theory. The overriding feature is management decision-making by the use of examples in the fundamental functions of management, and a study of the management of uncertainty, risk and change.

Topics covered will include planning; organising; leading and controlling; decision-making; break-even analysis; return on investment; and inventory control.

Life Cycle Analysis

ESE, BEBA, BEBBus
6cp;
Fields of practice: Environmental Engineering Program

Life cycle analysis (also known as life cycle assessment) is a systematic, general method of comparing the environmental, health, social and economic impacts of different products, processes and systems. It represents a sophisticated, holistic, system-oriented approach to reducing environmental impacts. The practical application of life cycle analysis still presents many practical difficulties, but simpler methods and approaches currently under development seem likely to address many of these Projects while maintaining its usefulness.

The objectives of this subject are to enable students to understand the key concepts and fundamental principles involved, the assumptions made in their development, and the ways the methodology is applied in practice.

Students will explore the application of Life Cycle Analysis to energy and other systems. For a number of selected cases they will follow the whole process of analysis, from initial decision making about the purpose and conduct of the analysis, through detailed study of the various systems involved, to evaluation, interpretation, reporting and critical review of the results.
Environmental Systems Modelling

ESE, BEBA, BEBus
6cp;
Fields of practice: Environmental Engineering Program

Upon completion of this subject, students should be able to demonstrate:

1. a critical understanding of the process and uses of mathematical and computer-based modelling;

2. experience in engaging and evaluating an authentic mathematical modelling process in an environmental systems engineering context;

3. competence in independent and peer-based learning, and application of a new area of mathematics and/or mathematical method, and software;

4. critical awareness of the ethical and political dimensions of modelling;

5. success in documenting, planning and managing a modelling Project in a group situation; and

6. continuing critical reflection on the learning and practices of engineers.

The subject will involve critical reading of some of the literature on the socio-political dimensions of modelling, as well as mathematical and technical literature on mathematical methods and models. Students will be introduced to classification of models, for example - physical systems versus socio-economic systems models; top-down versus bottom-up models; and linear versus nonlinear models, statistical versus deterministic models, and so on.

Students will spend the earlier part of the semester engaging in a common modelling Project. The environmental systems context of the Project may vary from year to year. In the latter part of the semester, students will engage in an individually or team-based negotiated learning contract where they will be formulating their own modelling Project in the environmental systems area. Assessment will consist of three learning contracts consisting of: a learning journal; common modelling Project; and a negotiated modelling Project.
Technology Assessment

CE, CEE, CSE, ESE, EE, ME, SE, TE, BEBA, BScBE
6cp;
Core

The objective of this subject is to provide students with an understanding of the development of impact as a concept, and to gain an appreciation of how it has been specifically constructed within the engineering culture.

Students will consider the concept of impact within the frameworks of technology assessment techniques; acquire an appreciation of and sensitivity to different interpretations of the impact of technologies; examine how different understandings of the concept of impact affect the relationships between technological professions and society; compare and critique methodologies and strategies for dealing with the impacts of engineering activity; develop skills in determining the appropriate use of various techniques used by decision makers to manage/determine the impact of engineering activity; develop skills in involving community in decision making regarding the impact of engineering activity; gain an appreciation of the diversity of engineering practice and its interdependence with other professions; experience and reflect on the interdisciplinary nature of engineering activity.

Environmental Audit

CEE, BEBA, BEBBus
6cp;
Fields of practice: Environmental Engineering Program

Environmental audit is a systematic, periodic, objective and documented evaluation of available resources, facilities and their management. It not only gauges the environmental status of a system, but also identifies environmental hazards. This subject will deal with environmental issues in a community including industries. Some of the topics in this subject include processes for water, sewage and trade waste treatment that are required to meet the guidelines set by regulatory bodies. This subject will also deal with processes for solid and hazardous waste management in a community and/or industry. An emphasis will be placed on selecting these processes in an integrated system to obtain sustainable solutions. The treatment processes selected
will initially aim to comply with environmental regulations and ultimately to achieve higher environmental performance.

**Project (12cp)**

CSE, EE, BEBA, BEBBus, BScBE
12cp;

**Project (6cp)**

CE, CEE, ESE, ME, SE, TE, BEBA, BEBBus
6cp;

Objectives of the Project are: to bring together and integrate knowledge and skills gained in the course as a whole, including engineering principles, planning and design, ethics, management, and communication, and to apply these to an initially unstructured Project formulated by each student in consultation with an adviser; to reinforce and develop competencies that have not been sufficiently emphasised in the student's choice of subjects or engineering practice to date; to define a substantial engineering study or design task, place it in context, and carry it to completion within a specified time and to a professional standard; to complete a comprehensive written and bound report that places the Project in context, defines its objectives, and describes the work done and the resulting conclusions or recommendations; to provide a bridge to the student's professional future, and opportunity to demonstrate professional competencies and capabilities; to provide scope to demonstrate initiative and creativity, and take pride in achievement.

Each student is required to undertake a substantial engineering Project, normally during their final year of study, and to prepare a formal report describing the work performed and the resulting conclusions and recommendations. The work is planned and carried out under the supervision of a member of academic staff. Both the work and the report must meet professional engineering standards. The Project may be in any area of engineering. Students may choose a topic relating to their experience in engineering practice, or an area of interest which they wish to study in detail. Typical Projects might take any of the following forms: literature review - a study of the available literature and a state-of-the-art appraisal of an area of engineering; design - the complete design of a substantial engineering artefact or system; experimental investigation - a comprehensive
laboratory investigation or testing program; research and development - original research of a fundamental or applied nature, or development of a new application of a particular technology; computer-based analysis - development or use of computer software to study the behaviour of an engineering solution; Project management - planning and management of a substantial engineering Project, normally in a workplace, business or community context; combining technical and management skills; impact analysis, planning, system design - study and analysis of an engineering solution in its economic, social and environmental context, integrating the engineering dimension with cross-disciplinary interfaces, and optimising overall system design, normally interactive with other professions.

Portfolio

An integral requirement of the course is the development of a personal portfolio by each student. The portfolio is used to document academic and workplace experiences, and to provide a personal resource for critical reflection and for educational and professional career planning, as well as personal development. The portfolio development process commences in the first semester of the course and is carried through to graduation, with increasing student autonomy in the content and structure of the documentation.