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A Journal of the Australasian Association for Engineering Education

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Editorial

The previous number of the AJEE was the special issue on the theme *Secondary to Tertiary Transition* and was very well received. That number is still very relevant and not just restricted to engineering but to all tertiary study. Copies of that number of the AJEE are still available.

This current number is a general one with 8 papers, but having some links between some of the papers. There are two papers on curriculum development, one relating to generic skills and diversity, the other to accreditation. There are also two papers on women in engineering with a view from Australasia and from Africa. The other papers are on management studies, engineering education in South Africa, sustainability and teaching German language and culture to engineering students.

This is my last number as editor of the AJEE as I pass over the role of editor to a new editor Dr Nathan Scott of the University of Western Australia and he will be aided by Dr Roger Hadgraft of Monash University and Dr Vic Ilic of the University of Western Sydney.

There has been obvious difficulty in maintaining more than one number of the AJEE each year since I took over as editor and I take sole blame for that. In a way this mirrors what I see as one of the difficulties facing the AAEE in general. That difficulty is keeping a momentum of an Australasian wide association when the Executive is composed of academics giving their time to AAEE whilst continuing with a very active teaching and research role in their own engineering faculties. Some of these positions, such as AAEE President, newsletter editor, AJEE editor etc are time consuming and have to be balanced with the other day to day pressures of a continuing professional role. As regards the AJEE there may be a move towards an electronic journal and to include expanded versions of the better papers from AAEE conferences. I will leave all that to the new editorial team.

In conclusion I wish to thank those who have supported AAEE and the AJEE in my years of involvement on the Executive Committee and as editor of the AJEE. In particular, I thank Mark Wainright for his significant leadership and support during the difficult times of the mid nineties when AAEE was seeking a more inclusive direction. Similar thanks must go to Erin Jancauskas and Cynthia Mitchell for their leadership of AAEE during the latter part of the nineties. Thanks also to Jean Armstrong as co-editor in 1997 and 1998. As reviewers for the AJEE I thank Robin Ford, Robin King, Anthony Maeder and Jeff Stewart for their regular and prompt reviewing. In recent times, similar support has come from Jackie Walkington, Wageeh Bowles and Vic Ilic.

I wish the AJEE and AAEE every success.

Terry Berreen

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Book Review

Engineering the Future

Preparing Professional Engineers for the 21st Century

by Brian Lloyd, Clive Ferguson, Stuart Palmer and Michael Rice

The Association of Professional Engineers, Scientists and Managers, Australia in association with Histec Publications.

Available from Histec Publications
$Aus49-00 [AAEE members $43] plus $Aus6-00 postage and packing.

This is a book that is of significant interest to engineers and engineering educators. Many will find the book controversial and it should lead to fruitful discussion on leadership in the engineering profession.

The main author is Dr Brian Lloyd who has significant experience in industry and engineering education and was National President of IEAust in 1993. Many AAEE members will also know him because of his attendance at engineering education conferences. He has also held executive roles with the Association of Professional Engineers, Scientists and Managers, Australia [APESMA] and, in fact, this book is published in association with APESMA. Lloyd is responsible for two-thirds of the book and particularly the early and later chapters.

Some of the co-authors, Clive Ferguson, Stuart Palmer and Michael Rice, may also be known to AAEE members. Clive Ferguson, currently a senior lecturer at Deakin in Mechanical and Manufacturing Engineering, attended and presented at engineering education conferences in the mid nineties. Stuart Palmer, also from Deakin, has been a frequent contributor to engineering education journals and conferences in recent years. As well he won the AAEE McGraw-Hill New Engineering Educator Award in 1999. He also has a paper in this number of the AJEE. Michael Rice is an engineer and has published on engineering labour force supply relating research and development to national economic performance.

This is a long book, it runs to 191 plus pages in A4 format. It is also long in reading because the format is tight with diagrams or tables tightly imbedded in the text or at the side of the text. This does not make for easy reading. There are 18 chapters of which the early ones give a history of engineering education in Australia. As mentioned above Lloyd is responsible for two-thirds of the chapters as well as the preface whilst the other authors share the remaining 6 chapters with Ferguson (3), Rice (2) and Palmer (1).

The book is certainly wide ranging on engineering education in Australia as well as a chapter on international comparisons. There is much detail coupled with tables and figures. However such a

wide ranging review opens the way for the criticism that some matters may be treated abruptly and in a superficial way. Examples of this could be the discussion on completion rates for Australian engineering courses, the relevance of double degrees involving engineering and the importance of the 1995-96 national Review of Engineering Education.

Some important sections of the book are in the final chapters [Chapter 15 (Professionalism in Engineering), Chapter 16 Professional Engineers in the National Economy, Chapter 17 Professional Employment in a Civil Society and Chapter 18 (Engineering beyond 2000)]. Lloyd's argument is that IEAust is no longer looking after the needs of or gaining the support of professional engineers. Further, it is not the association from which engineers take a responsibility for the societal consequences of their professional work. Lloyd ponders that it is perhaps EPESMA that is responding more significantly than IEAust to these challenges.

A book of this type is valuable for the material that it includes supported by a bibliography and appendices. That it asks us to consider the roles of IEAust and EPESMA is healthy and a matter that should be discussed by engineering academics and even brought to the attention of our students. I recommend this book to you and a publisher's information sheet on the book can be seen at page 136 of this number of the AJEE.

It must be pointed out that the AJEE has included this review and the advertising sheet to bring this book to the attention of readers for open debate and no financial inducement to the AJEE was offered or sought from the authors or publisher.

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WHITHER MANAGEMENT STUDIES IN AUSTRALIAN ENGINEERING UNDERGRADUATE COURSES

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In response to a perceived need for management studies in engineering undergraduate courses, the Institution of Engineers, Australia (IEAust) mandated a requirement for 10% of course content to be management studies in Australia in 1991. In 1996 a major review of engineering education in Australia recommended that the IEAust move from a course accreditation regime based on prescribed inputs to one based on demonstrated graduate attributes. In the move to the new accreditation system the policy on management studies in engineering undergraduate courses has become less definitive and more open to interpretation by individual educational institutions. A survey of recent engineering graduates suggests that those management skills most highly valued by graduates were generic professional practice skills, and that more opportunities to develop these skills in undergraduate studies would be beneficial. Survey respondents suggested the inclusion in the course of more *real world* examples of engineering management, including case studies, hands-on activities, industry visits, more in-depth coverage of topics, and presentations from practicing professionals.

INTRODUCTION

In 1991, Young reported on historical developments in Australia that culminated in the Institution of Engineers Australia (IEAust), the accrediting body for engineering undergraduate courses, requiring courses to contain at least 5% management content by January 1991, rising to *about 10%* by 1995 [1]. Since that time there have been a number of significant developments in engineering management in Australia that have influenced undergraduate management studies. This paper summarises those developments and their impacts on management education in engineering undergraduate courses, reports on recent

research on engineering management education in Australia, and outlines possible future developments in Australia.

HISTORICAL DEVELOPMENTS

As far back as 1968 it was identified that:

> *In all phases of practice in the profession the technical work is coupled, to a greater or lesser extent, with engineering management.* [2].

A 1972 survey of 1426 practicing Australian engineers found that 92% of respondents indicated management studies should be included at the undergraduate level [3], and yet a 1979 review of the Australian engineering workforce still found a wide variation and general lack of management studies in Australian undergraduate engineering courses [4].

Efforts during the 1980s by the IEAust National Committee on Engineering Management to introduce a mandatory component of management studies into undergraduate courses did not succeed [1]. The 1988 Australian government Discipline Review of engineering education surveyed both final year students and graduates and found that the course areas with the greatest discrepancy between required and actual emphasis were development of self-confidence and an understanding of motivation, industrial relations / management of people, engineering as part of the broader business context, the management of costs and resources, and oral communication skills [5].

In 1989 the IEAust established the Task Force on Engineering Management to draft guidelines for undergraduate studies in management. Following a process of consultation and review with stakeholders, in 1990 the Council of the IEAust approved the Policy on Management Studies in Engineering Undergraduate Courses. The policy became known as the *10% rule*, its essence being:

> *From January 1991 the Institution will require at least 5% management content in all professional engineering undergraduate courses and that the total of all management and management related components rises to the vicinity of 10% by 1995* [6].

It should be noted that this policy was not greeted with unanimous support by engineering schools around Australia, and in 1999, the level of compliance with the 10% rule still varied significantly; 36% of Australian engineering schools met or exceeded the 10% requirement; 36% nearly met the requirement (8 to 9 %); and the remaining 28% fell significantly short of the 10% requirement [7].

DEVELOPMENTS DURING THE 1990s

By 1991 the Task Force on Engineering Management had spawned the Society for Engineering Management Australia, which continues to this day as a technical society of the IEAust. 1992 saw the first meeting of Australasian Conference of Engineering Management Educators (ACEME), which has continued as an annual meeting of engineering management educators and practitioners in Australian and New Zealand, with international visitors. ACEME has been a valuable forum for networking and exchange of ideas relating to engineering management education.

1992 also saw the publication of the report Skills for the Future – Engineers and Scientists Achieving Enterprise Performance. This report was jointly prepared by the Association of Professional Engineers and Scientists, Australia (APESA), the Australian

government Department of Employment, Education and Training (DEET), the IEAust and a number of major engineering employers. This report concluded:

> *Australian engineers are well prepared in engineering technology, but not well prepared for the full practice of engineering it its managerial and business dimensions* [8].

This report also confirmed the importance of management studies for engineering students:

> *The deficiencies identified to Williams by employers are confirmed by critical feedback from young engineers...It is clear that even with recent moves by education providers to increase the proportion of management studies in undergraduate courses, skills in a broad spectrum of management, business, personal and interpersonal areas remains a pressing imperative for most engineering graduates as soon as they join the workforce* [8].

In 1993 the IEAust released its National Competency Standards for Professional Engineers. This document sought to *identify the overall balance of knowledge, skills, judgement, ethical standards and experience required by Professional Engineers* [9]. In the Competency Standards these objectives were achieved by defining 11 *units of competency*, which were further divided into *elements of competency*, which were further divided into *performance criteria*. Amongst the 11 identified units of competency there were found:

- professional engineering ethics and principles;
- management; and
- communication.

While acknowledging the independence of higher education institutions in determining course structure and teaching methods, the prescriptive nature of the Standards provided strong guidance for course design in all areas of engineering undergraduate course content, including management. The Standards reinforced the IEAust's requirement for management studies in undergraduate courses.

In 1994 DEET commissioned the Report on the Impact of the Discipline Review of Engineering. The inquiry's aim was to determine the impact of the recommendations of the 1988 Williams review. The inquiry noted that there was *quite strong* endorsement for the 1991 IEAust policy for management education in engineering undergraduate courses, particularly for the requirement for 10% management component in courses [10].

RECENT DEVELOPMENTS

In 1996 a major review of engineering education in Australia (sponsored by the IEAust, the Academy of Technological Sciences and Engineering, and the Australian Council of Engineering Deans (ACED)) was published. The review reaffirmed the importance of instilling graduates with an understanding of the context in which engineering functions, including, *...economics, finance, accounting, teamwork and competition...* [11]. The Australian review also proposed more freedom for, and scope for innovation by, individual engineering schools in determining their course content and modes of delivery, moving from a prescriptive system of accreditation to one focussing more on demonstrated outcomes and graduate attributes.

In response to the recommendations of the review the IEAust issued a revised framework for the accreditation of undergraduate courses in 1997. The new policy on the accreditation of professional engineering courses contained the following revised course content requirement relating to engineering management:

> *...integrated exposure to professional engineering practice (including management and professional ethics). This element should be 10% of the total course content* [12].

There was a perception that the revised policy on engineering management studies was weaker and more ambiguous than the previous *10% rule* of 1991.

> *Does this mean that this element could be interpreted as 1% management, and 9% professional ethics and other studies?* [13].

It became apparent in 1998 that, while the objectives of the new accreditation regime were widely supported, both the engineering schools and the IEAust were experiencing difficulty in implementing the operational requirements of the system. In June 1999 a task force comprising members of the IEAust and ACED was formed to review the accreditation process and devise a workable policy and process for accreditation of undergraduate engineering courses. In October 1999 a revised version of the Accreditation Manual was approved and issued. It has been subtly modified to de-emphasise engineering management studies even further:

> *...integrated exposure to professional engineering practice, including Management and professional ethics (about 10%)* [14].

In early 1998 the IEAust undertook a review of its competency standards, the second edition being published in April 1999. The new edition is more comprehensive than its predecessor, with the competency standards for professional engineer, engineering technologist and engineering officer included in a single volume. While the new edition still contains references to management competencies for professional engineers, competencies such as business management, project management and engineering operations are now classified as *elective*, and the *core* competencies for professional engineers have been reduced to *practice*, *design* and *self-management*[15].

FUTURE DIRECTIONS

It is clear that the final versions of the IEAust policy and procedures for the accreditation of undergraduate courses, and the competency standards for professional engineers have had and will have a significant impact on the nature of engineering management education in undergraduate courses in Australia. On the face of it, the changes in these documents will *water down* the overt references to the importance of engineering management in undergraduate preparation, and replace the explicit 10% rule with a more ambiguous requirement that combines management studies with engineering practice and ethics. While IEAust accreditation policy documents will still list a requirement for management studies in engineering undergraduate courses, the content and scope of such studies will be much more open to interpretation by individual institutions than has been the case since the 1991 *10% rule.* The continuing prominence of management studies in Australian undergraduate engineering studies will now largely depend on the belief of those responsible for course design in the importance of management studies for engineering students.

In the opinion of the author, the new accreditation requirement relating to undergraduate management studies could be seen unflatteringly as a movement of the goalposts to ensure that all institutions and courses will now satisfy the criteria without any further attention to management studies. It effectively gives a stamp of approval to the status quo and undoes more than thirty years of work in promoting the importance of preparing engineering undergraduates to appreciate the central role that management plays in

professional engineering practice, and in binding together all the elements of the engineering process.

It is noted that the recently released final version of the IEAust's Manual for the Accreditation of Professional Engineering Courses contains the statement that universities seeking accreditation of professional engineering courses will be required to have in place a quality management system that encompasses, amongst other things:

> *Substantial participation by practising professional engineers, and leading employers of engineering graduates, in the engineering school's forward planning and in its processes for ensuring educational quality, including assessment of graduate performance.* [14].

The historical literature described above shows that practicing professional engineers in Australia have been strong advocates for the introduction of management studies into engineering undergraduate courses. If, under the new course accreditation regime, practicing professional engineers do play a significant role in the development and review of courses, then the inclusion of engineering management studies in undergraduate courses may still receive the importance it requires.

WHAT CONSTITUTES AN ENGINEERING MANAGEMENT STUDIES SYLLABUS?

Just as an engineering school has to devise an overall curriculum for a course of studies, it must also develop a sensible, integrated and coherent syllabus for an engineering management stream within its courses. In the past, clear guidance was provided by the IEAust through its course accreditation requirements which referenced its Guidelines for Management Studies in Engineering Undergraduate Courses [6], and more broadly through its National Competency Standards for Professional Engineers. Even though the Guidelines were quite detailed, providing a rationale for management studies in undergraduate engineering courses, suggesting a model study structure comprising 17 units of management studies, and suggested contents for each of the units, they were clearly prefaced with the rider that they were not intended to be prescriptive, and that each school should devise their own approaches and subject arrangements. The Guidelines, while no longer referenced as part of the current formal IEAust accreditation process, still provide valuable direction as to what constitutes an engineering management studies syllabus for undergraduate programs.

Another important source of guidance in curriculum/syllabus design should be the teaching and learning objectives of an individual institution. At Deakin University this guidance comes from the Teaching and Learning Management Plan, which states that:

> *Deakin University's strategic priorities for teaching and learning...(are to)...Identify the knowledge and qualities which will prepare students and other clients for new opportunities...and to ensure these are reflected in our educational programs and partnerships* [16].

While there may be many objectives of undergraduate studies, such as preparing some students for higher degrees by research and/or preparing a *new generation* of professionals with new values to reconstruct the profession, etc, a key objective of undergraduate studies must be to prepare graduates to operate effectively in the practice of their chosen profession. In this regard, an important insight into the value and relevance of a management studies syllabus will be obtained from the recent graduates of that engineering course.

SURVEY OF RECENT DEAKIN ENGINEERING AND TECHNOLOGY GRADUATES

Context

The Deakin School of Engineering and Technology offers three year Bachelor of Technology (BTech), four year BE, Master and Doctoral engineering programs in flexible delivery mode. The undergraduate programs are delivered on-campus, full-time for conventional entry students. Mature age students may study the programs off-campus and/or part-time. As part of a review of the engineering management stream at Deakin University, a survey of recent graduates was undertaken to determine their perceptions of the current management studies syllabus, and to identify what management skills had proven to be valuable in their professional practice.

Methodology

Using the student information database, graduates from the years 1996 (first graduates of the new School of Engineering and Technology at Deakin University) to 1999 were identified. These students were sent the survey by post, using their last recorded address. The survey included a reply-paid envelope so students could return their response at no cost. As required by University research ethics procedures, participation in the survey was anonymous and voluntary. The survey sought information under the following categories:

- demographic information — age; gender; study mode;
- experience in engineering practice;
- experience in management roles;
- identifying management skills that had been important in practice; and
- evaluating the effectiveness of the management stream in the Deakin undergraduate engineering program.

Based on the 17 unit model syllabus from the IEAust Guidelines for Management Studies in Engineering Undergraduate Courses, and supplemented by results obtained from two prior surveys of mature age engineering students [17] and Australian engineering management academics [18], a 45 item management skills inventory was developed, as presented in table 1, and respondents were asked to indicate which of these management skills had been important to them in their professional practice since graduation.

Table 1: Management skills inventory used by survey respondents.

Communication skills	Project management	Legal / law
Supervision & leadership	Accounting & finance	Economics
Quality management	Professional ethics	Marketing
Organisational behaviour	Operations management	Business strategies
Project evaluation	Human resource manage.	Theories of management
Teamwork	Lifelong learning	Systems approach

Time management	Public relations	Maintenance management
International business	Strategic management	Cost estimation
Risk management	Environmental manage.	Industrial relations
Design management	Supply management	Change management
Dealing with customers	Decision making	Negotiation
Report writing	Contract management	Forecasting
Motivation	Competition	Conflict resolution
Occupat. health & safety	Creativity	Information management
Logistics	Inventory management	Work/time study

Results

From a total 135 graduates from the period 1996 to 1999, 17 surveys were returned as not deliverable. From the remaining 118 potential respondents, 38 completed questionnaires were received, a response rate of 32.2%. The age range of respondents varied widely (23 – 54 years), with a mean of 30.8 years and standard deviation of 7.5. The proportion of female respondents was 21.1%; the proportion of male respondents was 78.9%. The proportion of on-campus students was 68.4%; the proportion of off-campus students was 31.6%. The breakup of the engineering disciplines studied by the respondents was: Manufacturing – 55.3%, Environmental – 26.3%, and Mechatronics – 18.4%. The years of work experience reported by the respondents varied from 0 – 6 years, with a mean of 2.2 years and a standard deviation of 1.4.

The employment sectors reported by the respondents covered a wide range, including public sector, private industry, manufacturing, IT, consulting, building, education and postgraduate studies. The job functions reported by the respondents covered a wide range, including director, lecturer, manager, designer, project manager and research and development. The range of specific management roles reported as held by respondents is given in table 2.

Table 2: Management roles reported as held by respondents.

Supervisor	Project manager	Team leader
Contract supervisor	Maintenance manager	Assistant site supervisor
Business unit manager	Director	Business devel. Manager
Head draftsperson	Regional environ. manager	Production manager
Engineering manager	Student representative	Supervisor for trades
Area manager	Plant project supervisor	

Figure 1 shows the frequency with which respondents indicated that particular management skills had been important to them in their professional practice since graduation.

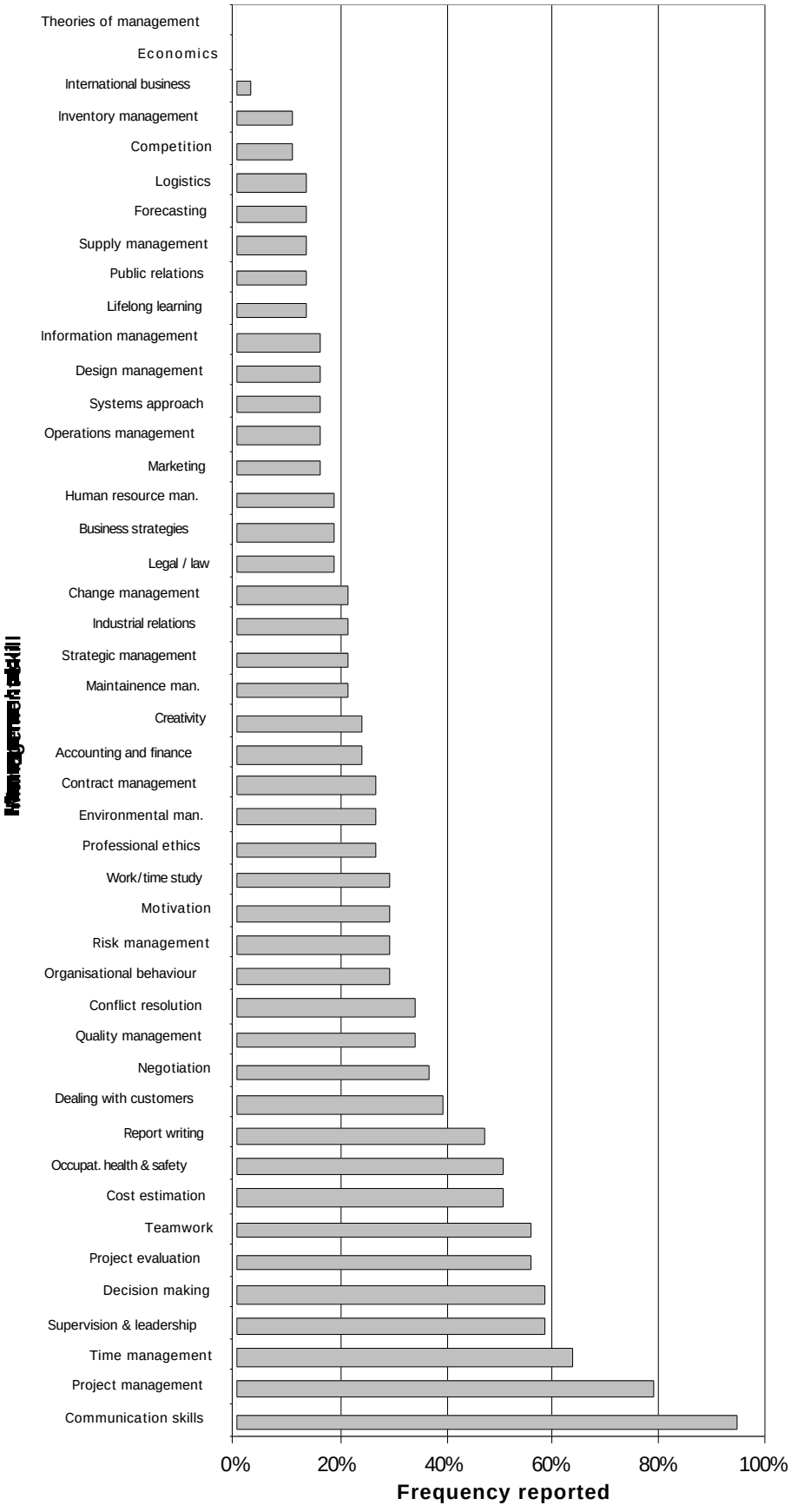


Figure 1: Importance of management skills as identified by respondents.

The following additional skills were identified by respondents as being important to them: *capital expenditure justification, marketing of services, empathy, organisational skills, scheduling, interpersonal interaction across the organisational hierarchy, and coaching.* Respondents were asked to evaluate the effectiveness of their undergraduate management studies. For a number of statements regarding their management studies, respondents were asked to indicate their agreement or otherwise using a five-point Likert-style scale. Table 3 shows the results; the mean agreement rating and standard deviation for each statement are given (based on a rating scale of 1 = strongly disagree, 2 = partially disagree, 3 = unsure, 4 = partially agree and 5 = strongly agree).

Table 3 Respondent evaluation of effectiveness of undergraduate management studies.

Statement regarding management studies	**Mean rating**	**Standard dev.**
Overall, the engineering management component of your undergraduate studies has been of value to you	3.8	1.0
If you entered engineering directly from secondary school, your management studies helped prepare you for real engineering practice	3.4	1.1
If you entered engineering as a mature age student, your management studies helped formalise your understanding of management gained from your prior work experience	3.9	1.2
If you studied principally <u>on-campus</u> as an undergraduate, your classroom activities and assessment tasks helped develop your understanding of engineering management	3.4	1.1
If you studied principally <u>off-campus</u> as an undergraduate, your course materials and assessment tasks helped develop your understanding of engineering management	3.8	1.1

Respondents were asked to indicate any ways in which their undergraduate management studies could have been improved to make them more useful and relevant. Table 4 shows the responses received.

Table 4 Improvements to management studies suggested by respondents.

More real case studies
Teams, customers, budgets, contract management, tenders/specs, industry visits
Dealing with people, conflict resolution, effective meetings
Law, contract law
Negotiation, marketing, presentations by experts, teamwork
Projects, contracts and tendering, standards
Real HR, supervision, delegation, ethics, accepting authority
Communicating with all types of people
More hands on, more oral presentations
More on motivation and development
Project finance
Group work
Supply contracts, oral communications
Project management, project evaluation
Presentations by local managers
Quotation methods, maintenance management
Project management, scheduling, organising, more hands on, less theory
Skills in communication to large groups, interpersonal skills
More real life instead of theory
More in-depth units instead of a crash course
Team playing and open communication
More real world situations, rather than textbook situations
Body language

Outcomes

The fact that 12.6% of the originally targeted recent graduates were no longer at the most recent address recorded for them highlights the difficulty in maintaining contact with students once they leave the university. The gender and graduating discipline proportions of the target potential respondent group were known, permitting a comparison with the actual respondent population. The proportion of female students in the target group was 16.3%, this was not significantly different from the respondent group ($\chi^2_1=0.469,\ p>0.49$). The graduating discipline proportions of the target group were Manufacturing = 54.8%, Environmental = 20.7%, and Mechatronics = 24.4%, this was not significantly different from the respondent

group ($\chi^2_2=0.886$, $p>0.64$). This suggests that actual respondent population is a representative sample of the target potential respondent group.

The most frequently reported management skills (reported as important by 40% of respondents or more) include *communication skills*, *project management*, *time management*, *supervision and leadership*, *teamwork*, *decision making*, *project evaluation*, *cost estimation*, *occupational health and safety*, *report writing* and *dealing with customers*. These first eleven skills are all important generic professional practice skills that highly practical, action-oriented activities that members of the engineering workforce are likely to be involved in on a regular basis. The survey reveals that these skills are important even to recent graduates.

At the other end of the scale, *economics* and *theories of management* received no score at all, suggesting that they are viewed as too theoretical or too remote from the engineering practice of recent graduates. In between, there are a large number of management skills that were reported as important by less that 40% of respondents. Some of the management skills in this middle band are possibly more specialised than generic, such as *risk management*, *environmental management*, *maintenance management*, *legal/law*, *marketing* and *public relations*, and hence reported by a smaller proportion of respondents. Other activities in the middle band may relate to higher level management issues that many recent graduates may not yet have experienced, such as *contract management*, *change management*, *strategic management*, *business strategies* and *systems approach*, and therefore again have a lower rate of reporting.

Overall, the value of the undergraduate management studies component of the courses at Deakin was rated highly, with a higher overall rating having a positive correlation with respondent age; the mean respondent age in each rating category was significantly different ($f=3.57_{3,34}$, $p<0.024$). Older students are likely to have had more experience of the engineering workforce, and hence had an opportunity to experience the *management* component of engineering work. It is the experience of the author that many students early in their undergraduate studies (particularly students entering directly from secondary school) experience some difficulty in appreciating the relevance of their management studies. The overall high rating of the management studies suggests that exposure to the real world of engineering practice quickly gives graduates an appreciation of the value of the management component of engineering.

The clear message from the suggested improvements to the management studies stream is a desire for more exposure to those aspects of management practice already most highly valued. An even clearer message is the desire for more exposure to the *real world* practice of engineering management.

DISCUSSION

Other international reviews of engineering education re-affirm the importance of engineering management studies in undergraduate courses:

> *It is clearly recognized that many engineers progress into managerial and top executive positions in industry and government. For such individuals the foundation should be laid in college for an understanding of human relationships, the principles of economics and government, and other fields upon which the engineering manager can build.* [19];

> *Engineering Faculties should:...emphasize design, problem solving, the impact of engineering on society and the environment, communication, teamwork, leadership and practical experience...* [20];
>
> *The real world is not as precisely defined as technical courses at school and university would lead students to believe...The varied problems that arise in daily professional life are not so restricted. They demand varied responses, with an integration of insights brought to bear from many different perspectives (technical, manufacturing, psychological, marketing, historical, economic, etc.).* [21].

Various Australian reviews and reports into engineering education (some of which are identified above) have reached the same conclusion. One clear indication that management skills remain crucial for engineers post graduation is the number of engineers that seek postgraduate studies in management. In the United Kingdom 32% of MBA students are engineering graduates [22]. In Australia the largest MBA program is one designed principally for engineers and focussed on the management of technology [23].

The survey of recent Deakin graduates suggests that those management skills most highly valued by graduates were generic professional practice skills, and that more exposure to opportunities to develop these skills in undergraduate studies would be beneficial. A large range of other management skills were valued as important, depending on the discipline and/or employment sector of the graduate. Only highly abstract management skills were not rated as important by any respondent. While the overall survey rating of the value of undergraduate management studies was high, engineering undergraduates tend to take some time to appreciate the value of their management studies [24]. One possible solution to this issue is suggested from the survey results relating to how the management studies stream could be improved, that is, recent graduates suggest the inclusion in the course of more *real world* examples of engineering management, including case studies, hands-on activities, industry visits, more in-depth coverage of topics, and presentations from practicing professionals.

Australia's *10% rule* has been held in high regard internationally as a benchmark for management studies in engineering undergraduate courses. With the requirement for management studies in engineering undergraduate courses now ambiguous and weakened, it would be a shame to see the issue of engineering management studies for undergraduates *go off the boil* in Australia, and for its *withering* to go largely unremarked upon.

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BIOGRAPHY

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DESIGNING THE ENGINEERING CURRICULUM TO CATER FOR GENERIC SKILLS AND STUDENT DIVERSITY

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The engineering profession requests that graduates exhibit particular generic skills as well as an understanding of the traditional content in engineering education. This is a challenge when also trying to cater for the needs of an increasingly diverse group of students. To truly acknowledge the role of these skills in engineering subjects or courses requires an adaptation to the general model used for curriculum planning and implementation. This paper briefly establishes the rationale for the consideration of generic skills, and suggests an additional element of design to enable their integration into educational programs. It suggests that integration is the key concept that affects the definition of goals, content, teaching strategies and assessment. The views expressed are based upon two dominant assumptions evident in engineering education discussion at present; firstly, that the graduate qualities required for professional practice are being emphasised in industry; and secondly that the diversity of engineering students is increasing. In terms of curriculum development, a philosophical shift in thinking is necessary towards a more holistic and integrated approach.

INTRODUCTION

Issues identified in the 1996 review of engineering education in Australia *Changing the Culture: Engineering Education into the Future* [1] are echoed in similar reports published elsewhere in the world. The 1994 ASEE *Engineering Education for a Changing World* [2], the American Accreditation Board of Engineering and Technology *Engineering Criteria 2000* released in 1997 [3] and reports from the European association SEFI [4] all acknowledge the changing nature of engineering practice in response to societal and economic imperatives. These must be reflected in the education of engineers for the future. In particular, two issues are highlighted in this paper. Firstly, the diversity of engineering students is increasing and must be acknowledged in tertiary education. Secondly, the individual graduate qualities required for professional practice are changing from the traditional, almost total, focus on

engineering content to the inclusion of generic attributes that prepare graduates for a *lifetime of unrelenting change in technology and employment* [5]. Discussion of these two issues complement one another from a curriculum design viewpoint.

The challenges for engineering educators are enormous. Rather than focus on specific issues that face individual engineering academics, this paper provides a broad view to clearly establish the context in which designers and implementers of engineering education curriculum must operate. It is proposed that the interrelated issues of student diversity and generic skill acquisition cannot be appropriately addressed without a broad view of how curriculum is developed, as these issues underpin decision making about the curriculum. The following establishes a brief rationale to provide context, then identifies assumptions upon which a change to the general model for curriculum development is based. The major adaptation is then explained and supported with specific examples relevant to the engineering education context.

RATIONALE

Graduate Attributes

The question of how to prepare engineering students of today to be successful graduates of tomorrow has always provided a challenge. Employers are demanding graduates who are able to operate in an environment of constant change - of international cooperation and competition and technological innovation. The importance of a thorough grounding in mathematics and science with a sound understanding of the principles of engineering science is undeniable. Specialist knowledge aligned to specific branches of engineering is also fundamental for effective practice. However in the past few years there has been a call for the explicit recognition of other knowledge, skills and attitudes necessary for the development of the professional engineer. These include the knowledge relating to economic, societal, management and environmental matters that impinge on engineering decisions, and the need to be aware of ethical practice [6]. Engineering practice in the changing professional world also requires that the skills of communication, problem solving, team work and life-long learning be a focus in the development of engineering graduates. How to incorporate what appears to be *extra* into the curriculum provides a daunting task.

It is proposed here that the challenge is not just to examine **what** is taught/learned, but **how** it is taught/learned. This is why the adaptations to the standard model of curriculum development presented later in this paper are suggested. There is a need to look at courses in a broad view. Knowledge and skills that are not part of *identifiable engineering content* need to be integrated into the total learning experience of the student during the course in order to develop attributes which will be needed long beyond the student phase, into the phase of the employable engineering professional.

Student Diversity

Political, social and economic pressures over the past couple of decades have opened up access to higher education for a wider group of people [7]. The move from elite to mass post-compulsory education is reflected in the desire of the profession to employ engineers who more closely represent the population they service [1]. The student population (and the potential student population) demonstrates a wide diversity, exhibiting differences including

gender, ethnic origins, first language, geographical distribution, socio-economic background, interests, experience and preferred learning styles. An engineering curriculum that caters for the diverse needs is an inclusive one. Inclusivity relates to ensuring that everyone has equal opportunity for involvement in educational, social and cultural activities through ensuring practices are non-discriminatory and allow for diversity. Courses, which value diversity, are designed to be inclusive of all students and offer sufficient flexibility and choice in structure, content, methods of teaching and assessment to acknowledge such diversity. They value differences in students' backgrounds and provide opportunities for all students to develop the attributes expected of course graduates [8].

There is a potential for the various stakeholders in the engineering education environment to benefit from an inclusive curriculum. The IEAust report [1] concluded that an engineering education system, which embraces diversity, will attract a wider range of students and therefore better represent the society the profession serves. The tertiary institution, which acknowledges and caters for the diverse learning needs of its students has the potential for greater success rates and therefore recognition as an effective educator of engineers. For enrolled and potential students, there is the attraction of more flexible and relevant options for study, which in turn heightens the image of the institution. In essence, the recognition of inclusive curriculum enhances an evolution of the engineering education culture.

When specifically considering the concept of engineering cultural diversity, King, McGregor and Marks [9] acknowledge different kinds of culture viz the engineering discipline culture and the academic culture. Within the interrelated context, the different cultures affect and change one another. The aforementioned authors claim that the pervading *deficit* model of teaching, where participants are encouraged to change to suit what exists, needs to change to a *productive diversity* model. *One product of a "deficit" model of cultural diversity is a culture which blames the students rather than one which is willing to explore new ways of approaching the teaching and learning issues arising from such diversity* [p.433]. Inclusive curriculum seeks to move away from the concept of a deficit model of curriculum.

ADAPTING THE CURRICULUM MODEL: INTEGRATING ELEMENTS

Theorizing about curriculum development has taken, and continues to take, many paths, reflecting the social, philosophical and political viewpoints of theorists. Although there is no definitive model or theory of curriculum, there are elements of curriculum development, which are commonly agreed upon as basic considerations [10]. A situational analysis, the development of objectives, content, teaching strategies and assessment, and the evaluation of curriculum effectiveness are *standard* aspects of a curriculum model. These are represented by the stages A, C and D in Figure 1. It is the stage identified as B on the figure that constitutes the unique element proposed here – that of integrating elements.

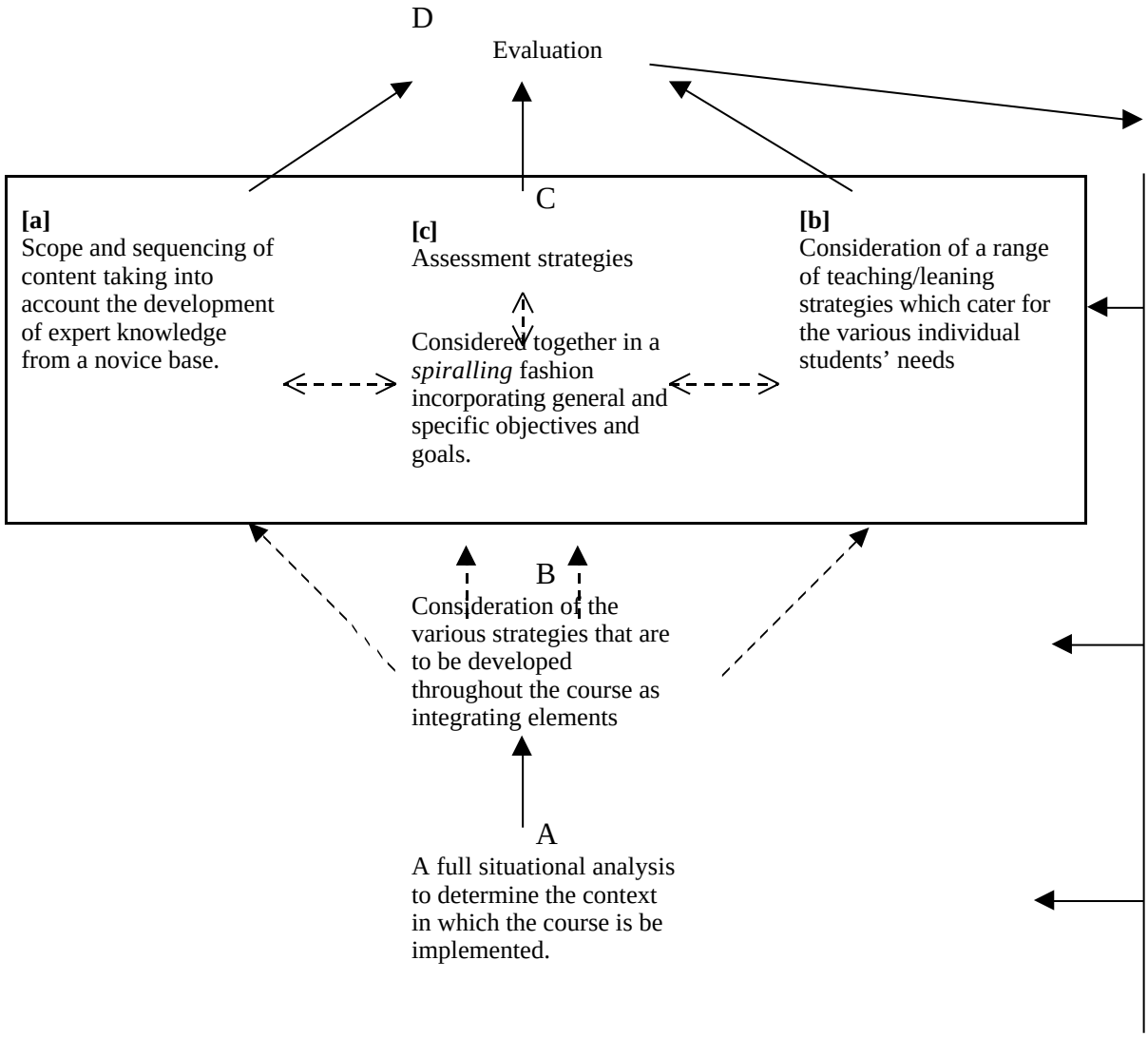


Figure 1: Modifying the curriculum model.

Integrating elements

This stage of the process is not usually found within existing models of curriculum development. It comprises the consideration of various *elements* that define how the course may be taught and how various parts may be incorporated to develop a cohesive whole.

Integrating elements are defined here as those factors of the course, which do not belong to specific content, but are considered as inherent to the developmental teaching of the course. The elements are categorised and discussed as:

1. those that are related to the students' learning and therefore and influenced by the diversity of student characteristics, and
2. those that relate to overall course objectives and are articulated in terms of graduate qualities.

Individualising student learning

To clarify, individual student learning is discussed here using engineering scenarios. As acknowledged earlier in the paper, there are a number of characteristics that identify differences in students. Three are addressed in the scenarios, viz. geographical isolation, student experience, and student ability.

Consider the University of Southern Queensland (USQ), which enrols around 75% of its engineering students in the distance mode. Staff acknowledges that it is difficult to design the teaching experiences for students who are geographically widely spread and whose choice of part time study needs to fit in with their working life. The elements of time and space to study are variable. Also, students who choose to study full time on-campus often face financial imperatives that require part time employment to enable continuation of their study. They require a more flexible approach. One suggested integrating element throughout course design that addresses this situation is the making available of alternative pathways for study. If flexible modes of study (and therefore teaching) are provided, students can negotiate a pathway, which is of *best fit* for their purposes. By providing face-to-face *classes*, traditional distance materials (print plus audio-visual and contact opportunities) and on-line materials, students are able to select their most appropriate pathway. This element of alternative pathways addresses a need of student diversity and needs to be part of the structural design at all levels of the course.

A second example of an integrating element is that of provision for variations in student experience. Many assumptions are made about the students who enrol in a course, and upon these decisions are made. When students come directly into a tertiary course from high school, there is a likelihood that their study and life experiences are fairly homogeneous. This is not necessarily so. Assumptions about homogeneity are even more unlikely to be correct when students studying part time and/or at a distance are considered.

Data recorded about students enrolled in engineering in the distance mode or studying part time at USQ, for example, demonstrate that most are in full or part time employment – usually in the engineering field. The experiences that these students bring to the study context are variable and often specific to particular engineering disciplines. These experiences have direct consequence on the links students make between *new* course knowledge and their existing knowledge. While the variation in life experiences of mature aged students is perhaps more obvious, the types of experiences school leavers bring to study cannot be taken for granted.

In the development of a course curriculum, the difference in experience needs to be taking into account. It may be that students can apply for exemption from particular elements of the course content based on documentary evidence from employers. Perhaps students can *test out* of particular course content or skills through the demonstration of competency. It may also be that because a student is very familiar with a particular context, eg the thermodynamics of engines in harbour vessels, that they need to be encouraged to diversify their understanding by applying principles to other areas.

Acknowledging that students have this variable background experience stimulates course developers to consider the way theory and practice is presented to take advantage of the student's context. One strategy is to offer choice in the way application of theory is demonstrated by students. Students need to be able to make links between what they know and what is being presented if accommodation of the new material is to occur. Making this

explicit throughout the course as an integrative element ensures that the diverse experiences that students bring to the study environment are identified and catered for.

Thirdly, means of catering for differences in student ability is seen as an integrating element. Similarly to the scenario above, assumptions are made about the academic abilities of students enrolling in undergraduate courses. The requirement for pre-requisite school subjects for students enrolling in engineering courses differs amongst institutions. Therefore, the level of understanding in content areas can be variable. In Queensland, for example, the range of Overall Position scores at entry can vary widely. With access to university study available to many whom left formal schooling some years ago, the range of abilities in a number of content areas is further widened. A mature aged student who has worked in industry for ten years or more, for example, may have not had sufficient access to computer use or computer education, or may have had only very specific computer use related to current employment. To assume that students entering a particular course have computer skills and knowledge of the same level would be erroneous. This could similarly be the case with areas such as mathematics, written communication and physics. Even if the student had formal school study in the area, it may have some time since it was used and therefore is in need of revision.

The implications for course developers in this type of case is consideration for the provision of additional support where needed. Although it would seem appropriate that this is needed at the beginning of the course, it is not unreasonable to expect that there may be additional points at various levels of the course. Supporting ability differences is considered an integrating element throughout the course because of the range of ability differences may manifest themselves at different times depending on the need for particular knowledge or skills.

A course that is designed and implemented under the assumptions that students are homogeneous in experience, ability and study opportunities, negates to consider the diversity of the students. It also negates to consider the basic principle of effective teaching and learning – that all students are individual, and while certain commonalities can be identified, so can many differences. This process does not advocate that individual study programs are developed, but that elements are considered and supports put into place to acknowledge, and positively utilise, the differences.

Achieving non-content specific objectives – the generic skills

As discussed earlier in this paper, there are objectives related to course content that do not *belong* to any one body of knowledge. These are skills and understandings that are developmental and are required by the student to be a competent practitioner and life-long learner. These include, among others, the ability to communicate in an engineering environment, to think critically and reflect on current practice, to diagnose through the use of systematic thinking processes, and to develop an understanding of collaborative practice. One way to accommodate these is to develop specific units devoted to them; another is to integrate them into current units; and a third way is a combination of these.

It may appear easier to develop distinct units and *make someone responsible* for them. While distinct units such as communication are in evidence, it is suggested here that these skills are ones that need to develop in the context of growing understanding in the engineering environment. This is the understanding behind the positioning of this type of decision making in the curriculum model. Overall consideration and decisions need to be in place **before** specific planning. Decisions relating to the development of graduate attributes

are the concern of all staff involved in the course if the knowledge and skills are to be best understood and used widely by students. To isolate them would be to hinder transfer of understanding and perhaps downplay their importance. The design of teaching and assessment strategies at the same time as the identification and sequencing of *engineering content* would assist the students to develop knowledge and skills in context and at the same time, reduce the necessity for excessive separate treatment.

This is not to deny however, that there is *new* knowledge associated with the development of generic skills and therefore concerns will be raised about a course workload that is perceived by many to be already overloaded [11]. This opens up a contentious issue for many. What actually constitutes the core content? It is contentious because it moves from the discussion of educational effectiveness to include operational issues such as resources, and attitudinal issues such as the *protection of academic territory.* To take on board the need for developing generic skills will require modification of engineering content to accommodate them. For this reason, it is suggested that the quest for ways to integrate skills through the whole course offers a more favourable option than to an attempt to *add on.*

Communication, teamwork, problem solving and critical thinking skills are readily integrated. Providing opportunities such as learning in groups, presenting assessment findings using a variety of written and verbal communication styles, and using the contextual application of projects, allow students to meet such objectives. It is obvious though that the achievement of such objectives cannot be allowed to happen *ad hoc.* They need to be planned for and considered in the light of the whole course. An example of integration can be seen in the course planning at the University of Southern Queensland. Initially, an engineering communication unit was developed for first level students. The faculty is now developing benchmarks in communication skills to be demonstrated at each level of the course with a view to reducing the need for a separate unit.

Other general qualities identified as important include the development of social, cultural, environmental and ethical awareness. Consideration of the way the course is taught also opens up opportunities for the integration of these. Such opportunities can include the use of strategies for teaching/learning and assessment that involve placing engineering content in context. Application of engineering theory through the analysis and evaluation of real life examples offers investigation of the wider implications for engineering practice.

The key notion underlying this discussion is that factors of student diversity and generic skill development must be designed explicitly at the course planning stage.

Consider an example of how generic skill development and student diversity are interrelated in the design and implementation of curriculum. Students whose first language is not English form a considerable proportion of current engineering enrolments in Australian universities. For many of these students, English competence is sufficient for day-today functions, but the requirements for operating in an engineering environment in English requires a much greater grasp of the language. These students not only require the fostering of engineering communication skills, but also the improvement of overall English competence to cope with the specific language usage. As all students meet communication requirements at various levels throughout the course, on-going support in communication skills specific to the field of engineering would supplement the ESL students' learning as they are presented with new language and concepts. Support is necessarily interconnected with the content of the course. Such a situation also demonstrates the need for collaboration with support areas within the university. It is not suggested that engineering academics become ESL specialists,

but that they plan *outside* support opportunities in the course. Support in English, Mathematics, Physics etc may also be sourced from outside the engineering education environment.

IN CONCLUSION - A PHILOSOPHICAL SHIFT

The additional stage of the curriculum process presented here, embodies a need to adopt a changed philosophical approach regarding the catering for student diversity and graduate outcomes in engineering courses. For those curriculum developers who base their courses almost solely on the engineering content, there is a need for a philosophical *shift* in their thinking. This is a shift to a more holistic approach to course design which aims to acknowledge the various characteristics of students and the integration of knowledge and skills through modifications to curriculum implementation. While it is necessary for planners to focus on the scope and sequence of engineering content, there is a need to consider the integrating elements as well. The learning of generic skills requires the same sequential development throughout the course as do the theoretical and practical elements. Consequently, modifications within the course that occur from time to time then have the guidelines to ensure continuity of learning.

This request that course developers consider a stage of curriculum design that incorporates the integrating elements as outlined, comes at a time of significant change in higher education. It is totally complementary with the trends to move from teacher-centred to student-centred education, from knowledge transfer by lecture to knowledge acquisition through project-based work. These mean a major change in the role of faculty staff and a major challenge for the course developers. They reflect the changing needs of the engineering profession and the students who aspire to be part of it.

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BIOGRAPHY

Jackie Walkington is a lecturer in the Faculty of Education at the University of Southern Queensland where she works with undergraduate and postgraduate students in the areas of curriculum design and implementation, and pedagogy. Her current research is focused primarily on a PhD thesis investigating the development of a systematic process of curriculum development in higher education. In particular, this investigation is focused on a case study within an engineering faculty. Her interests in engineering education stem from working with engineering academics in the design of distance education materials early in the 90's. Her passion for effective teaching practice based on sound curriculum design underpins her work in this field. Her on-going objective is to challenge the decision-makers in an environment of change.

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USING ACCREDITATION TO DRIVE CURRICULUM DEVELOPMENT IN ENGINEERING

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The Engineering Council of South Africa, in line with engineering accreditation bodies in several countries, recently adopted an outcomes-based approach to the accreditation of engineering qualifications. The new procedures for accreditation require institutions to provide evidence that students have achieved a specified set of learning outcomes when they graduate. Three case studies of curriculum development in engineering in response to this development are described. While these cases developed independently of each other they each reflect an attempt to use the new accreditation process to stimulate an improvement of their educational programmes.

INTRODUCTION

The past two decades have seen two waves of curriculum development in engineering at universities in South Africa. The first wave took place in the late 80's and early 90's and focussed on the needs of the increasing numbers of black engineering students entering the historically white universities, many from disadvantaged educational backgrounds. The focus in this wave was on the creation of *bridging* programmes, extended curricula and other academic support activities to assist the *new* students. Several institutions significantly restructured the first part of the engineering curriculum to address issues related to easing the transition from high school, orientation to studying at university and providing foundational experiences of engineering and technology.

The second wave began in 1998 when the Engineering Council of South Africa (ECSA) adopted an outcomes-based framework for the accreditation of university engineering programmes. ECSA was responding to several stimuli. Firstly, the changing requirements for

engineering work and the need to ensure the safety of the public suggested an outcomes-based and competence approach. Secondly the introduction of a National Qualifications Framework in South Africa required outcomes-based standards to be defined for all professions. Thirdly, the Washington Accord[1] provided evidence of a growing consensus internationally amongst the accrediting bodies for providers of engineering degrees of the need for a shift towards a focus on outcomes in an attempt to match the outcomes of engineering education more closely to the requirements of the workplace [1].

In the early stages of implementation, the outcomes-based accreditation framework has been seen, both nationally and internationally, to generate an administrative response with very little impact on the educational aspects of engineering programmes [2]. However the case studies described in this paper highlight how changes in the accreditation system have opened up opportunities for substantial curriculum development.

The first two, based at the University of Cape Town (UCT), describe different approaches to the overall review of the degree programmes in civil and chemical engineering, while the third focuses on a review of final year courses in electrical engineering at the University of the Witwatersrand (Wits). In all three cases efforts were made to avoid the jargon associated with outcomes-based education and to keep the specification of performance criteria as simple as possible. The emphasis was on helping staff review what they were trying to achieve and how they assessed it.

In each of these cases educational change has been driven by what Fullan [3] describes as *individual, skilled change agents pushing for change around them, intersecting with other like-minded individuals and groups to form the critical mass necessary to bring about continuous improvement.*

INTERNATIONAL TRENDS IN ACCREDITATION

Many countries have systems for accrediting educational qualifications that satisfy requirements toward professional registration. Historically, accreditation criteria have focuses on the content and process of education, with the process being regarded as a proxy for the outcomes. The strong focus on content led to perceptions of the quality of the programme as the product of breadth and depth: the larger the better.

Demands for all manner of specialist knowledge on the part of the graduate are no longer heard, rather, the graduate is expected to have a sound core of fundamental knowledge in mathematics, the basic sciences and engineering sciences. Some specialist knowledge, coupled with the attitudes and abilities to support lifelong learning, is regarded as sufficient at entry to employment. In line with these developments ECSA's new requirements focus on a strong fundamental basis in mathematics, basic sciences and engineering sciences and a limited amount of specialist study in a 4-year degree programme.

In the new outcomes-based approach, one primarily driven by employers, a new view of the quality of engineering education has emerged. Generic abilities such as problem solving, analysis, synthesis, communication and teamwork, particularly in a multidisciplinary environment, have become explicit requirements with high priority. The following set of generic outcomes have been adopted by several accrediting bodies, including ECSA:

- The ability to solve complex problems.

[1] Co-operation between USA, UK, Canada, Australia, New Zealand, Ireland, Hong Kong and South Africa on accreditation of engineering degrees.

- The ability to analyse artifacts, systems and situations.
- The ability to design using a systematic approach.
- The ability to plan and conduct investigations and to analyse data
- The ability to choose, use and evaluate the result of engineering methods and computational tools.
- The ability to communicate orally and in writing with peers, other professionals and lay audiences.
- The ability to assess the impact of engineering activity on society, the economy and the environment.
- The ability to work effectively in a team situation and across disciplinary boundaries.
- A critical awareness of the professional responsibilities of the engineer.

An outcomes based method is seen as the most effective way of specifying and ensuring the achievement of these new requirements. Hence the accrediting bodies within the Washington Accord are moving, at different speeds, towards the development and implementation of outcomes based criteria and accreditation policies and procedures to evaluate programmes.

The adoption of an outcomes based approach is closely coupled to a move toward formal competency standards for professional registration and assessment of candidates using direct evidence of competence. The standards for professional practice are determined ultimately by the dual requirements of the protection of the public and effective engineering in the workplace.

Accrediting bodies enable inputs from both employers and academics in the specification of the requirements for accrediting a qualification or programme. They do not specify how the programme is to be implemented but rather what the programme must achieve. Education providers have the freedom to implement programmes in diverse ways to provide quality teaching and learning and to demonstrate that the required outcomes are being satisfied. For the university degree ECSA has adopted exit level outcome specifications with the emphasis on the outcomes of the programme as a whole rather than on individual modules or courses.

CASE 1: FROM THE COURSE LEVEL UP.

The undergraduate civil engineering programme at UCT was changed substantially during curriculum development initiatives in the early nineties that modernised the content and created greater coherence and a more holistic approach to facilitating student learning. In many ways these changes were driven by the same factors that lead ECSA to adopt an outcomes-based approach.

The civil engineering curriculum reflects the need for graduates with multiple competencies primarily achieved through courses using a design and synthesis approach and with considerable emphasis in complementary studies. In fact, the curriculum was difficult to cast in a content and structure framework at the last ECSA accreditation visit. As a result staff readily identified with the new system of accreditation. It is seen as providing a more appropriate vehicle for evaluating the curriculum and allowing more flexibility for curriculum and course developers to focus on the key objectives rather than course content.

The academic staff felt that the programme already delivered on many of the new ECSA outcomes and therefore did not require a complete re-design. However staff recognised the need to develop a coherent quality assurance system to ensure continuous improvement in the civil engineering programme. Most of the staff had lost sight of the objectives set in the earlier review and endorsed the need for a quality assurance system in which the general programme outcomes are more important than examining knowledge at course-level.

The department decided to adopt the ECSA set of outcomes [4] and the preparation for the ECSA accreditation focussed on an audit of the existing curriculum using the following tools:

- an initial workshop on outcomes-based course and curriculum design
- a standard course template
- course articulation matrix, and the
- curriculum articulation matrix (link table)

In the course template, course presenters focussed on describing course learning outcomes in terms of knowledge, skills and values, and the learning activities used to achieve these. At the course level, outcomes were stated in general terms. The course articulation matrix was used to link outcomes with appropriate learning activities and assessment techniques.

The course outcomes were placed in a curriculum articulation matrix that linked the programme outcomes to courses in which they are developed and/or assessed. A third dimension was added to the matrix by indicating the level of the outcome as introductory, intermediate or exit level in the appropriate cell of the matrix. Finally, the column of outcomes was interrogated and each outcome was categorised in terms of the ECSA outcomes. This enabled areas with suitable coverage or deficiencies to be identified for attention.

This process is seen as the first-step in the development of a continuous improvement model.

At first glance there was sufficient coverage in the civil engineering programme in terms of learning objectives and learning activities to satisfy the ECSA outcomes, but in some cases suitable assessment techniques were lacking. This was partly because the majority of the course presenters still relied on formal written examinations for the bulk of their assessment tasks. The next phase of the improvement model needs to focus on appropriate assessment techniques that match the required learning outcomes. In particular, the assessment of outcomes at exit-level needs to be sufficiently well-defined and robust to satisfy internal scrutiny and external accreditation.

The approach adopted by the department has been from the bottom-up with the first phase resembling an audit of course objectives – as envisaged by the presenters themselves. This approach was followed as it was feared that the staff might perceive a top-down approach as being too prescriptive and out of touch with the realities of the classroom. This has the additional advantage that subsequent curriculum audits are based on as-is practices rather than as-hopefully-is perceptions.

It should also be mentioned that the curriculum development exercise received strong support from the departmental leadership.

CASE 2: FROM THE PROGRAM LEVEL DOWN

The Chemical Engineering Department at UCT has devoted a large amount of time over the past few years to improving teaching and learning, primarily in response to very low pass rates in certain courses [5]. In the course of this work the curriculum has developed a high degree of coherence both vertically, between years, and horizontally, across courses in a year. The challenge for the department recently has been to review the curriculum using an outcomes-based approach.

The approach adopted by the Chemical Engineering department differed from that of the Civil Engineering department in three respects. Firstly the time devoted to curriculum development was incorporated into the existing system of weekly staff meetings. This meant that for most staff the process did not require additional time. The second difference was the decision by the chemical engineering staff to formulate their own programme outcomes rather than accept the ECSA list. As a result the curriculum review process started at the programme outcome level and moving down to course level. At the end of the process a check was made to ensure that these outcomes included all of the ECSA outcomes. Thirdly a facilitator from outside the department, namely the first author, was used to assist in the curriculum design process and provide staff development input where necessary.

As in the case of civil engineering, the process received strong support from the departmental leadership with the aim of developing a continuous improvement model and was seen as forming part of on-going efforts to improve teaching and learning in the department rather than being solely directed at preparing for the accreditation visit.

A series of workshops of about 2 hours were held every 5 or 6 weeks over a period of 10 months. Each workshop focussed on a specific task and introduced staff to new elements in preparation for work that lay ahead (Table 1). At the end of each session staff members were assigned work. Small task groups and co-ordinators were appointed to ensure that the follow-up work was completed and submitted for discussion by the next workshop. The workshops revisited many of the curriculum development tasks over several months at increasingly complex levels to help staff get used to some of the new concepts in outcomes-based curriculum and course design.

Table 1: Chemical Engineering's Curriculum Development Workshops at UCT.

Date	**Focus**	Introductory item	**Follow-up (Homework)**
Aug 1999	Defining Programme Outcomes UCT / SAQA / ECSA	Assessment planning	Task group to refine programme outcomes
Oct 1999	Defining Programme outcome components	Assessment planning template	Task group to define outcome components. Few staff to develop Assessment plans.
Nov 1999	Designing an Assessment Plan	Course description template	All staff to develop course descriptions. Few staff to develop Assessment plans.
Feb 2000	Writing course descriptors	Link Table: Linking courses to programme outcomes	All staff to help develop Assessment plans. All staff to develop Link Table.
Mar	Assessing student learning	Defining assessment	All staff to refine Link Table in

2000	Part 1: Review Assessment Plans and *Link* table	criteria and *levels* of assessment.	terms of levels and review Assessment plans in the light of the Link Table.
May 2000	Assessing student learning Part 2: Case Study - 4th year chem eng design course	The SOLO model (Structure of the Observed Learning Outcome)	Preparation of a summary overview of curriculum development process. Prepare for pilot use of SOLO model.

Defining the programme outcomes from scratch helped to bring all the staff on board the curriculum development process. The list that was generated incorporated all of the ECSA outcomes but was written in language the staff felt was more understandable. The wording and detail of the programme outcomes was reviewed over several months. During this time two of the outcomes which staff had originally wanted to include were put *on hold* because incorporating them into the curriculum turned out to be more difficult than originally thought. Each programme outcome was broken up into component outcomes for which it was felt it would be possible to develop assessment plans.

The process followed was:

- define programme outcomes
- define component outcomes for each programme outcome
- design an assessment plan for each component outcome
- write course descriptors – using course template
- link courses and component outcomes
- design assessment

The following tools were used to take the process down to course level:

- the assessment planning template,
- the course template
- the link table (curriculum articulation matrix).

The writing of performance criteria associated with effective assessment methods was found to be the most complex task. However repeated reviewing and re-writing of these criteria over a period of months led to a visible improvement in the ability of most staff to produce realistic assessment plans.

Staff found the course template less of a problem to complete but again needed practice to re-formulate course objectives in terms of outcomes. The link table, similar to the articulation matrix used by Civil, listed the programme outcomes and components along the vertical axis and all the courses on the horizontal axis. It showed where the individual component outcomes were developed and assessed in the programme. The table also indicated the level of assessment (initial, intermediate, exit-level) at each place where assessment occurs.

The final focus of the workshop was on designing appropriate assessment tasks. Staff were introduced to Biggs' SOLO model as a framework for the assessment of high-order skills [6]. Several staff members began experimenting with the use of this model.

CASE 3 –FOCUS ON FINAL YEAR COURSES

The B.Sc.(Eng.) programme at Wits is accredited by both ECSA and the Institution of Electrical Engineers (IEE). While the IEE accreditation, last performed in 1997, did not have comprehensive outcomes specifications, it had a strong emphasis on the department's own quality assurance mechanisms. As a result of that experience, the department instituted an internal quality assurance process requiring that course specifications include a clear statement of objectives at course level, thus moving towards an outcomes focus.

The Electrical Engineering (EE) Department at Wits has been engaged in a curriculum development project spread over several years. There has been a slow but sure shift away from focus on content alone to an awareness of the importance of the generic outcomes, particularly problem solving, communication, design and placing engineering activity in a wider social and economic context. This shift has been in response to the new accreditation criteria and staff's awareness of changing requirements in the workplace.

The department has engaged in both bottom-up and top down activities in the move to an outcomes-based approach. A bottom-up approach was used in an exercise carried out in July 1999. Each course was analysed in terms of the weight it gives to each of the ECSA outcomes. A result of this exercise is a sharpened focus on assessment of outcomes through specified performance criteria in a number of courses - particularly those with design or project components. The next step is to perform an audit of the assessment of students against ECSA's specified exit level outcomes. The audit requires the teaching staff to identify where the assessment of particular outcomes is performed, what he performance criteria are and what is considered satisfactory performance.

The Design and Laboratory Project courses described below produce clear evidence that assessment is taking place and is effective. Other areas, particularly the "soft" outcomes prove harder to verify and are the subject of ongoing development and audit.

Transformation Of Final Year Project Courses

The Wits EE curriculum contains both a major design and a laboratory project in the final year. Until four years ago, the assessment in both courses used a marking schedule which awarded a proportion of the mark to different aspects: for example problem statement (5%), literature survey (10%), analysis (10%), design (15%) and the merits the merits of a technical report (20%). While these factors are related to the formal outcomes published by ECSA in 1998, satisfactory performance required simply that the student amass 50% of the total mark.

With increasing awareness of outcomes, the staff became uneasy with the phenomenon that a student could pass one of these courses with the combination of engineering work well done and badly reported or, conversely, mediocre work well presented. The final year Design and Laboratory project courses were therefore re-specified in terms of outcomes and characteristic performances that provide evidence of satisfying the outcomes. In the Design course, the specified outcomes cover the design process as well as written technical communication. The design process outcomes are:

1. Analyses and understands specification, including documentation requirements.
2. Assembles and evaluates information required for design.
3. Identifies and develops solutions.

4. Completes necessary tasks including analysis, synthesis, and optimisation.
5. Evaluates and uses design tools.
6. Identifies, makes and evaluates key decisions.
7. Adopts and uses an effective problem-solving strategy.
8. Manages project according to schedule and delivers documentation on time.
9. Critically evaluates design and design process against specification.

The required written communication outcomes are:

1. Plans and structures the technical report.
2. Selects material for inclusion and makes logic behind the work accessible.
3. Uses acceptable style and English.
4. Makes detailed design information accessible.
5. Uses drawings, diagrams, tables, graphs and other illustrative material.
6. Creates an impact.

The Laboratory Project outcomes focus on experimental or investigative design, technique and analysis of results, as well as on technical communication.

The student's performance against each criterion is rated using a five-interval scale: *Unacceptable/Poor/Acceptable/ Good/Excellent.* The student is required to attain at least an average rating of *Acceptable* on the five-point scale in the design process and technical communication outcomes. Thus, assessment within the design course verifies that both sets of outcomes are satisfied by every student. The Design and Laboratory project courses thus perform exit level verification of ECSA outcome numbers 3 (Design and Synthesis), 4 (Investigations, experiment and data analysis) and 6 (Written communicative competence) (ECSA, 1998).

The university system is still geared to marks in each qualifying course. The student's overall mark for the Design course is obtained by a mapping process. To obtain a pass mark, the student must rate at least satisfactory on both sets of outcomes. Marks above and below the pass mark are determined by the combination of the two ratings. For example, a first class mark of 75% or greater requires at least one *Good* and one *Excellent* rating.

DISCUSSION

The shift to outcomes-based accreditation of engineering programmes at South African universities has triggered off a mixed response with initial attitudes ranging from enthusiasm to sceptism and disinterest [2]. The approaches adopted can be categorised as follows:

1. Re-write existing contents and structure documentation in the outcomes-based format required for the new accreditation system.
2. Check the course objectives and curriculum practice against the desired outcomes and adjust where necessary.
3. Review the entire programme as part of a system of continuous improvement.

While approach 3 is clearly the intended educational goal of the ECSA accreditation process, it is likely that most institutions, due to time and other constraints, will adopt approaches 1 and 2.

Approach 1 is essentially an *administrative response* where the courses and programme are written in the new format and terminology, and there is little or no change in

content-driven approach to the curriculum. Existing practice in final-year projects and thesis may be used to demonstrate the achievement of the required outcomes.

We speculate that as both the institutions and the accreditation panels are relatively inexperienced in outcomes-based accreditation, ECSA is likely to use the first round of outcomes-based accreditation visits to play a developmental role rather than a punitive one. It is our view that where institutions have adopted the administrative approach staff complacency in existing practice is likely to be further entrenched and an important opportunity will have been lost to stimulate creative educational development to address current shortcomings or the changing needs in the workplace.

Approach 2 is essentially an *audit and fix strategy* which is probably the most practical approach where time and workloads prevents a more holistic approach along the lines of 3. In this strategy deficiencies are identified by an examination of the current curriculum. In the top-down method the overall objectives are tracked down to course level while the bottom-up method audits course outcomes and their accumulation through the curriculum to exit levels. These outcomes are then compared against those of the accreditation body to ensure compliance or identify deficiencies.

In many cases overseas, accreditation panels have been satisfied, in the first round of visits, with programmes that had identified deficiencies and had started implementing plans to address them. For example in many places appropriate assessment practices were still being developed to meet the burden of proof of achievement of several of the required outcomes.

The audit and fix strategy represents a first step in setting up a continuous improvement process for programmes and a movement in the direction of approach 3. It is clear that the new accreditation process has the potential for helping all programmes to move in that direction. However, there is a danger that the efforts required by approach 2 in preparing for the first accreditation visit might not be sustainable beyond the visit. The longer term vision implied in the approach 3 would include a more appropriate pacing of time and energies focussed on achieving best educational practice over the long term rather than simply meeting the requirements of the accreditation visit.

CONCLUSION

Our collective experience leads us to strongly endorse the following viewpoint,

> *We suggest that whilst many academics may view the requirement to have all qualifications…in an outcomes-based format…as an encroachment of their 'academic freedom', that, provided we, in higher education, are allowed to do so in our own terms, that the exercise could prove to be beneficial to students and meaningful for those committed to improving their teaching. [7]*

In the context of engineering education the process of moving towards outcomes based approach needs to be sensitive to the needs and constraints of institutions and the profession. In particular these developments must take place within a framework of institutional and staff development and be phrased in ways that are understandable and meet the needs of both teaching staff and their industrial counterparts. It needs to be acknowledged that the buy-in to the new approach by the majority of staff is likely to occur over several phases: commit in principle, struggle with concepts, struggle with practice, put into operation, continue with business as usual and accept the need for regular renewal. The process has best chance of success if it is driven by strong educational leadership in the departments and the profession together with the resourcing and support of key staff who serve as educational change agents.

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THE *PROBLEM* OF WOMEN IN ENGINEERING – IS IT WOMEN, ENGINEERING ACADEMICS, CURRICULUM OR ENGINEERING – WHERE TO ACT?

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The *problem* of women and engineering education has been conceptualised and addressed in a variety of ways over the last 20 years. Despite this, the participation of women in engineering education in many western countries has yet to reach 30%. This paper attempts to provide a framework for understanding why this situation exists. It maps the interrelationships between paradigms of education – vocational/neo-classical, liberal/progressive and socially critical - and theories of gender. An analysis of the shifts in engineering education suggests that the view of engineering education as located within the vocational/neo-classical paradigm of education is no longer appropriate. Rather, engineering education reflects movement across and between each of the paradigms. Within paradigms, certain understandings of the individual *student* and gender theories intersect and are reiterated. These shared understandings have come to frame particular, and at times unhelpful, ways of conceiving the *problem* of women and engineering. Recent feminist research arising from studies based on poststructural theories of gender is establishing new directions for advocacy initiatives, increasing the range of actions which together work towards resolving the continued under-representation of women in engineering.

INTRODUCTION

Since the 1980's engineering has been the focus of considerable feminist research and interventions aimed at securing equality and equity for women. In New Zealand and Australia, the significant annual increase in women's participation in engineering during the mid 1980's to mid 1990's has recently been declining, leading to a plateau in participation rates in the range 15-20% [1,2,3]. This situation mirrors an international trend [4,5,6].

In consideration of the continued under-representation of women in the engineering profession, the Institute of Engineers, Australia (IEAust) Review of Engineering (1996) [7] stated:

> *.... engineering schools should apply increased effort to providing women with the incentive to pursue careers in engineering, to improving their participation in engineering education, and to ensuring that the environment is conducive to their staying (p54).*

The *problem* of women and engineering as defined by the IEAust Review, is multifaceted: incentives, careers in engineering, participation, teaching and learning environment, engineering school *environment*. Other literature [eg 8], including education policy documents, describe women as a *disadvantaged* group of individuals. They are lacking essential attributes (eg skills/tinkering experience etc) for engineering and, therefore, need support to enter and succeed in this non-traditional area. A further argument refers to how the structure and culture of engineering, which has been developed around the lifestyles and interests of men, represents a significant barrier to women's participation [6].

Given the complexity of the *problem*, where and how do we act to solve the *problem* of women in engineering? Is it women, teachers, curriculum or engineering? Which strategies might be profitable at a local site?

WHY DO WE WANT WOMEN IN ENGINEERING?

Three arguments, consistent with international literature, are cited by engineers, educators, government and industrial organisations in response to *why* we want women in engineering. The first argument relates to disparity between men/women demographics of the population as a whole compared with the demographics within engineering institutions at all levels. Even after nearly 20 years of research and interventions into the *problem* of women in engineering, the participation of women is still variable across all the levels and disciplines of the profession. In certain disciplines, such as resource engineering women often comprise upwards of 40% of a class cohort, while in mechanical engineering, women are seldom more than 10% of the cohort [9].

A competitive, sustainable economy and the contribution of each individual towards its sustainable development form the basis of the second argument. Embedded in this argument is the belief that we cannot assume traditional engineering roles and practices will continue to dominate the future of engineering. Women are often identified as critical players in the future of engineering as they bring *another*, important perspective to our growing knowledge of sustainability and sustainable practices. The perspective of women is viewed as essential in transforming contemporary engineering towards its own sustainable future [7].

The third argument advanced suggests that the ability of a nation to compete successfully in the *global* knowledge economy is dependent on the nation having enough scientists, engineers and technologists. These groups in the workforce are deemed to be integral in creating wealth for society in a competitive world. Unfortunately, at a time when many believe we need to be producing more science, engineering and technology (SET) graduates, there is a global decline in the number of students enrolling in SET courses. The participation of women, and those from other marginalised groups, is one way of increasing this diminishing human capital.

WAYS OF DEFINING AND SOLVING THE *PROBLEM*

Given that we adopt one or all of these arguments, the challenge for engineering education in relation to women is: how do we increase the full and effective participation of women in engineering? The framework developed in this paper provides a map of the complex intersection of fields of knowledge relating to women and engineering education. It draws on feminist theories of gender, which present gender not as a fixed attribute of men and women, but as a relationship between, and defining, men and women in particular ways[1]. Particular ways of understanding gender have informed many of the *change* strategies designed to *solve* the problem of women in engineering.

However, little of the current theorising of the field of *women and engineering* [4,10,11] addresses and integrates the education paradigms reflected by educators, teaching and learning practices, and programmes. Tonso [12] describes that while particular cultural/gender practices are embedded in pedagogical practices, attempts to reform these cultural/gender practices were not successful. She maintains this was due to the power of normative ways of thinking about pedagogy that could not recognise students where unable to be successful in engineering education because they did not conform to the *norms* on which success is based. This illustrates the importance for advocacy, in particular, to understand the way(s) education paradigms inform, constrain and are responsive to specific strategies relating to women in engineering.

Drawing on classical education theory [13], engineering education can be understood to span across the vocational/neo-classical, liberal/progressive and socially critical paradigms of education. These paradigms are not new but each is internally consistent and conceptually distinct. Each paradigm highlights commonly articulated differences in the engineering education community about *what engineering education is* and *what it is for*. One of the central arguments of this paper is that these differences (and the dominance of one perspective in a local engineering programme) can either enable or limit particular ways of conceiving both the problem and solution(s) of *women and engineering*.

VOCATIONAL/NEO-CLASSICAL PARADIGM OF EDUCATION

Table 1: Intersections – vocational/neo-classical education paradigm and gender theories (after Kemmis et al, [13]).

Paradigm of Education	Learning theory	Understanding of Gender	Focus of advocacy and interventions	Nature of interventions
Vocational/ neo-classical	Behaviourism, deficit models of the learner: *transmission* theories of learning eg Skinner, Ausubel, Gagne	Liberal feminism Men as *norm* population; women less than men but can be changed to be *like* men.	*Changing women:* Recruitment focus *Changing women:* Retention focus	role models, mentors, targeted recruitment, scholarships, career information, counselling. WIE support networks, extra tutorials, non sexist curriculum materials.

[1] In this paper, the use of men and women, masculinity and femininity are not to be conceived of at the level of the individual. Rather they are associated with groups (of men/women) or concepts relating to the gendered identity (masculinity/femininity) we ascribe to events/practices/***ways of doing things.***

The vocational/neo-classical view of education treats engineering education as a purposeful, technical and non-political set of activities, which delivers engineering graduates who can appropriately meet certain needs of society. Essentially, it prepares and/or develops students for work. It assumes a technical, linear relationship between the inputs (eg the student cohort), the process of engineering education and the key outcomes (eg the graduates).

Advocacy based on liberal feminist gender theories, addresses problems of under-representation through the remediation of certain *deficits* in girls/women which, it is argued, have the effect of impeding their progress in engineering. This understanding of women as *lacking* is consistent within this paradigm of education because through education we can provide for (or remediate) this *lack*. Advocacy concentrates on removing barriers restricting women in education include unequal access and inappropriate sex-role socialisation; hence activities such as mentoring and girls' only science/technology camps are supported. For women, achieving full potential is often associated with achievement in essential learning areas such as mathematics and sciences, and subsequent occupational choices. Hence, many interventions are aimed at ensuring that women who make decisions for engineering are supported in their endeavours to meet the entry criteria and be eligible to enter at the start of the engineering education continuum.

Achievements and limitations of advocacy in the vocational/neo-classical paradigm

The relative success of strategies focusing on recruitment and retention of women in engineering can be seen in the increased participation rates of women in engineering. At the University of Auckland, where a number of these strategies were in effect, participation measured across all years of the degree rose from around 8% to 18.4% between 1989 – 1995, up to 21% in 1998 [9]. The increase can be attributed to the long-term appointment of the Women in Science and Engineering (WISE) Liaison Officer in the School of Engineering. Comparable circumstances in Australian universities show similar trends, although the effectiveness of many WISE positions in Australia has been limited by the short-term, non-tenured nature of many of these positions.

However, as Roberts and Lewis [3] point out:

> *if the current level of increase continues, it will be the year 2055 before women and men choose engineering in equal numbers. This is the optimistic scenario. If the rate of increase continues to decline [referring to the plateau effect being observed globally] then equal numbers will not be achieved in the 21st century (p5).*

Recognising there are a range of factors, aside from gender, contributing to the declining participation rate, none the less, this decline also indicates that the *problem* is not able to be resolved using this advocacy approach alone. Walkerdine [14,15] states that since the assumption that women/girls are lacking is unchallenged, the strategies available for, and our understanding of advocacy, are limited and can only be those which rectify women's lack.

The liberal feminist understanding of gender can not adequately account for the women students who reject involvement in support strategies irrespective of whether they may actually need them. Further, to suggest (as some early feminist research does) that women who do not recognise they *need* assistance have a false perception of self, fails to explain the women students who are very able and successful within engineering and simply have no need to draw from any of these interventions.

LIBERAL/PROGRESSIVE PARADIGM OF EDUCATION

Table 2: Intersections – liberal/progressive education paradigm and gender theories (after Kemmis et al [13]).

Paradigm of Education	Learning theory	Understanding of Gender	Focus of advocacy and interventions	Nature of interventions
Liberal/ progressive	Constructivist-interactionist models of the learner as building cognitive structures through interaction eg Dewey, Piaget	Radical feminism Women are equal, but different to men. Difference is celebrated.	*Changing structures:* Gender inclusive focus – internal (pedagogy) *Changing organisations:* external (programme structures) *Changing culture:*	*Pedagogy:* move to student centered learning approaches: less competitive assessment practices; contextuality of learning, recognition of prior [non-technical] experience and understandings changing content and context of engineering curriculum; group work *Programme structure:* development of conjoint degrees new degrees and pathways eg resource management, environmental; social, political, ethical dimensions of engineering practice emphasised; introduction of non-technical knowledge and skills to curricula ***'Culture'*** or environment of engineering explored; implicit and explicit values of culture made known; women's experiences made visible

Liberal/progressive education is fundamentally concerned with the formation of character and the knower as citizen – the ideal of the fully empowered participant in the culture (both of *engineering culture*, and the broader culture of society). Engineering and engineers impact and contribute to environmental, economic, social and cultural aspirations of society. It is through engineering education that the engineer, as citizen, is empowered to act in ways enhancing and progressing the social good.

The shift in engineering education from the *production* of graduates to being concerned with the *[re]formation* of engineers - the development of the *whole* person [16] - reflects the influence of this paradigm. Three specific areas of curriculum reform have been important in facilitating this shift. The identification of *key* graduate attributes (widely supported by professional and industrial groups) such as teamwork, communication and critical thinking

have been a catalyst for curriculum change. *Sustainability* and the critical role engineer's play in sustainable development have brought the ethic of care and responsibility into the curriculum. Recognition of the increasing diversity of the student body, initially through different approaches to learning and learner-centered pedagogy but increasingly cultural and ethnic diversity, is addressed in the *inclusive* curriculum.

Whether led by advocacy, or informed by it, the imprint of the radical feminist theories of gender is clearly present in many of these curriculum reforms. Since the engineering *culture* has been identified as exclusive of women [17,18] advocacy has explored how the engineering culture is reproduced through education [19]. Making visible how *the way we do things around here* [20] admits or alienates women [21] has made it increasingly difficult to defend some of the traditional positions and assumptions of engineering education. For example, opponents of the traditional reductionist approach to engineering curriculum argue this approach privileges predominantly white, male, Western and heterosexist interests. Advocacy strategies tend to be directed at reorganising the curriculum so that it embraces women's ways of knowing [22] (eg contextualised and integrated curriculum) and reflects the social construction of engineering over time [23]. Alongside professional and other political interests, advocacy participates in the re-imaging of engineering. Rather than a scientific or technically dominated enterprise, engineering has been conceptualised in language, which reflects it as an enterprise that is interdisciplinary, involving people, service to the community, negotiation and entrepreneurial skills and exciting challenges [24]. Such an image, it is argued can make engineering more attractive for women who are drawn by the social implications of engineering outcomes [25].

Achievements and limitations of advocacy in the liberal/progressive paradigm

Radical feminist gender theory celebrates women's difference with men as opposed to making men the *norm*. The focus of advocacy on the *gender inclusive* curriculum challenged the existing *masculine* engineering pedagogy. But, as student cohorts become more ethnicity diverse women seem to have lost their place. The shift to *good practice* (ie student centered approaches to teaching) has been advantageous for many students, not just women. However, *good practice* in group work, for instance, has diluted the advantages for women particularly where issues of ethnicity and gender are not considered at all in the formation and processes relating to groups [11]. Changes to curriculum areas and the development of new degrees (particularly environmental engineering areas [4,26]) focusing on gender-inclusive approaches have been interpreted as *softening* or *diluting* [27,28] engineering. The implication is that women are unable to engage with the presumably hard (masculine) learning styles and concepts embodied in traditional curriculum. Thus, some gender-inclusive strategies while maintaining equity for women, continue to construct women as *unable* in some areas of learning.

While radical feminism has clearly empowered advocacy reform, it (like its liberal counterpart) fails to adequately explain the multiple and various ways women, both corporately and individually, experience engineering. Feminist critiques suggest the treatment of women as a universal category is itself problematic. Constructing difference from men in terms that assume *unity with/similarity to all women* [29] ignores that women are not a homogeneous group. This is clear from their stories: not all women are disadvantaged but some are; some women reject or ignore perceived *feminist* intervention and support; some

women find the environment in engineering school hostile, intimidating and/or chilly [21]; others are thoroughly captivated by engineering and succeed without apparent personal cost. While there have been some moves towards embracing this diversity and difference within the (overall) student body in engineering education, more generally feminist programmes have continued to work from the generalised category privileging a particular version of white, middle-class women.

SOCIALLY-CRITICAL PARADIGM OF EDUCATION

Table 3: Intersections – socially critical education paradigm and gender theories (after Kemmis et al [13]).

Paradigm of Education	Learning theory	Understanding of Gender	Focus off interventions	Nature of interventions
Socially critical	Social constructivist-interactionist model of the learner as reconstructing in his/her own knowledge a social reality that is socially constructed and subject to reconstruction through historical and political processes eg Berger and Luckman, Foucault, Gramsci, Althusser, Marcuse, Habermas	Poststructural feminism Men and women are not unitary or fixed variables, rather gendered identities are made in the culture	***Emergent themes only:*** Masculinity and femininity within the discourse of engineering Articulation of new engineering identities eg engineer as problem framer	Mapping the discourses; Identifying relations of power within these; Defining subject positions within discourse; Defining how gendered relationships are perpetuated; Listening to stories of successful women; Finding new methodologies for exploring the cultures of engineering Curricula theorising and redevelopment Professional competencies for a changing profession eg reflective practitioner, critical thinking

The very nature of engineering education as a *professional* degree and its often stated primary concern with the vocational (construed as employability) challenges the extent to which engineering education (or aspects of it) can be considered as consistent within the socially critical paradigm. However, the concept of education as reproductive of a culture, together with the work ranging from McIlwee and Robinson [18] through to the IEAust Review [7] have been important in establishing the dialogue around the *engineering* culture. Recent educational research (within the socially critical framework) critique the *discourse* [10, 30-34] of engineering education using the language and tools of other disciplines – legal, managerial, contemporary feminism, and sociology. The understandings of discourse[2] can provide

[2] Discourses define what is appropriate, current and valid in the field and how as educators and students we absorb guidelines as to the nature, scope and purpose of our own endeavours – that is, how our agency as individuals is moulded and constrained [35].

different perspectives on what/why and how we do engineering education, why and how change has been effective or impeded. This work has helped to highlight why *add-on* papers in *ethics, communication, history and philosophy of engineering* may have not had the impact in the student body originally intended. It has strengthened the shift towards increased integration across the engineering curriculum, together with a more clearly defined need to develop professional competencies able to deal with a changing profession (eg critically reflective, conceptual and innovative thinking) [7]. Similarly, this shift is reflected in attempts to locate and frame professional engineering activity within a technical, historical, cultural, political and economic context (viz the growth of (soft) systems thinking engineering [36]).

Emerging areas of advocacy in the socially critical paradigm

The important feature of recent feminist research in education congruent with a socially critical paradigm is the shift from gender, as a generalised category, to a term *in process*. For advocacy, an advantage of working with this gender theory is it affords ways of dealing with the different and contradictory experiences of women [and men] in engineering education. Using this theory of gender, research suggests engineering education makes certain meanings available to women engineering students which regulate what women students can/cannot do and who they can/cannot be [17,37-40]. These meanings become considered to be truth, are embodied in structures and mechanisms in educational practices and operate [re]productively in the identity/identities of self that women and men gain as students in engineering. For advocacy, three emerging areas can be identified, which are based on these theories of gender and the gendered effects of education.

In poststructural theories of gender, masculinity and femininity are defined as a binary – each needs the other to establish meaning. However, there exists a dominant side of this binary, masculinity, which limits the meanings available for femininity. Tonso [38,39] argues that particular versions of femininity exist because they enable rigid and narrow forms of masculinity to continue. Research has refocussed away from redefining what it might be to be a woman engineer – to what it might be to be a male engineer, therefore, making more possibilities for both. Henwood [10], after Pecheux [41], argues that to achieve this advocacy cannot simply reject the current set of meanings which define who a [male] engineer is, but needs to attempt to give *new* meanings to current experiences. This can occur through the construction of alternative discourses and meanings, for instance, the concept of engineer as *problem framer* rather than simply *problem solver*. The introduction of these *other* ways of thinking about the engineer becomes possible in the various new discourses of engineering emerging at the intersection of established ways of being an engineer (eg civil/chemical and environmental; electrical and mechanical). Advocacy can also work strategically within the established discourses to find ways to demonstrate and enable other valid forms of masculinity to be present in engineering which are not oppressive of women and other men. Copeland and Lewis [42] outline the use of *pro-feminist* men in presentations to male engineering staff and students in order to make visible the choices around what it might be to be masculine and an engineer (ie versions which are not dependent on a narrow definition of femininity). On a cautionary note, as these approaches might undermine the dominance of conventional heterosexuality - and given the close association of engineering with conventional

heterosexuality – a complete redefinition of what it means to be *masculine* in engineering is not likely to occur in the short-term [10].

The second emergent area for advocacy is the need to continue to support critical analyses of pedagogical structures - how they [re]produce students and how advocacy might work strategically within these structures. The growing field of cultural studies in SET education continues to reaffirm SET education assumes students share with SET practitioners particular worldview presuppositions about what the world is like, what questions are important, and what methods ought to be used in pursuing answers [43]. Full enculturation in the SET disciplines is often based on this shared understanding; without it, students achieve *communicative competence* [44] rather than meaningful learning. Hodson [45] writes:

> *the notion of SET education as enculturation into a community of practice requires students to cross cultural boundaries from their various subcultures into the subculture of SET disciplines. The chances of smooth border crossings are greater when all are clear about the nature of the enterprise, recognise the boundaries and the likely obstacles, and make concerted efforts to overcome them (p171).*

Understanding how this idea of *smooth border crossings* might occur in engineering education requires action at both generic (eg curricula) and local (eg specific strategies to facilitate student learning) levels.

Localised action can be illustrated by the following example drawing from teaching and learning three dimensional (3D) modelling in CAD. Implicit in CAD systems are assumptions regarding how engineers visualise and interact with the world. In 3D modelling, the user will manipulate the 3D object by *picking up* an object and turning it around in order to view it from a variety of angles. In this practice, it is the object that moves relative to the user who is the fixed point of reference. However, for some students this manipulation is not possible. Rather than explain this solely on the basis of theories of spatial representation, this lack of success may be also connected to the different ways students understand themselves in relation to the material world (eg through different cultural, spiritual relationships). *Front end* software can be developed which permits all students to work in a three dimensional space while maintaining their own, different, ways of interacting with the subject/object manipulation. Students benefit from this type of approach to engineering knowledge as they can become more aware of their own *ways of doing things* and they can defend these ways against the conventional. At the same time they can become skilled at finding ways of moving between their *ways* and the conventional engineering way of working with knowledge (eg conceiving spatial relationships) [46].

Generically, despite the increased interest in the history, philosophy, sociology of engineering, and attempts to shift to a *student-centered* pedagogy, the fragmentation of engineering curricula continues to be an impediment to student learning [47,48]. Engineering education needs better ways to conceptualise the structure and links between the theoretical and practical concepts and elements in its knowledge field [49] and the ways this knowledge field relates to *other* (particularly social) fields. This will enable curriculum development to find a better balance between the positivist approach to engineering knowledge (as evidenced in reductionist approaches to curriculum) and *process oriented* curricula required for the development of professional competencies required for engineers to fully participate in the contemporary debates concerning a sustainable planet.

Finally, since women are no longer assumed to be a unified group, no one solution or strategy will work for attracting all women to engineering. Current research supports advocacy adopting an *eclectic* group of approaches that recognise women have various and unique experiences and backgrounds that contribute to various (as opposed to a universal) reasons for recruitment and attrition. Similarly, the approaches (outlined in this section), in isolation, will be unable to effectively resolve the problem of women and engineering. Yet, since advocacy is generally funded on short-term contracts, the need to provide quantitative evidence of increase in women's participation itself works to limit the range of strategies it is possible to employ.

DISCUSSION

Within each of the three paradigms of education – the vocational/neo-classical, liberal/progressive and socially critical – there exist distinctly different ways of conceptualising what education is and what it is for. In contemporary engineering education each of the three paradigms are present, however, Carr and Kemmis [50] contend that a coherent view of education cannot be composed of fragments of all three paradigms. Rather, they argue curricula must be located within a particular paradigm, and at best can only represent practical compromises of all three paradigms. Consequently, in education literature, engineering education has long been associated with the vocational/neo-classical paradigm and indeed this assumption is true of some contemporary engineering curricula. *Add-on* elements present in these curricula (eg ethics, communication) reflect compromise, albeit unhealthy at times, between opposing ways of understanding the role and purpose of engineering education (eg vocational/neo-classical and liberal/progressive paradigms). Ultimately, these *add-on* endeavours are likely to fail to meet their aims because they do little to shift the established understanding of what engineering education is and hence, have no intrinsic value within traditional curricula.

However, this rigid approach to understanding education (particularly at the tertiary level) is an unhelpful way of looking at engineering education. Rather than contemporary engineering curricula being a situation of compromise, change more closely follows a dynamic or fluid movement between and across each of these paradigms. If the boundaries across each paradigm are considered to be flexible, these paradigms can respond to external forces for change, however, their response is likely to be filtered through each paradigms particular *rules* or *ways of doing.* Within curricula, it is possible to detect the tensions arising from different conceptual frameworks and meanings concerning engineering education. In the last decade, the tensions between the vocational/professional orientation and the liberal/progressive paradigm have been evident. Engineering schools are called to provide technological education closely geared to the needs of the country, but not confine graduates so closely to their speciality that their personal development as autonomous well-rounded engineers is minimised [51]. In some engineering programmes capability development and *humanities/management thinking* have been comprehensively integrated in redeveloped curricula confirming a pedagogical shift across paradigms. More recently, tensions in engineering education arose from the influence of the socially critical paradigm particularly concerning issues around sustainability. In response to these tensions, engineering educators are exploring ways of making engineers understand their role, responsibility and professional practice as *problem framers* rather than simply *problem solvers*.

Notwithstanding this, an overview of engineering education literature relating to advocacy supports the view that one paradigm may dominate in [re]defining engineering education both conceptually and practically (at the local site). An effect of thinking about engineering education in a specific (eg dominant) way is it narrows the focus of the *problem* concerning the under representation of women in engineering and therefore, limits the preferred solutions. This narrowing is reiterated by the intersection of gender theories theoretically consistent with the internal constructs of the paradigm. Within the vocational/neo classical and liberal/progressive paradigms which traditionally dominate engineering education, liberal and radical feminist gender theories conceptualise gender in fixed categorical ways and can be shown to be consistent with the understandings of the nature of the student in the respective paradigms. Advocacy is effective (and permitted) to the extent it is grounded in these shared understandings. Advocacy may attempt to reform aspects of engineering education from outside a dominant paradigm or shared understanding of gender. However, often in these attempts advocacy is forced to underplay its most radical claims in order to win a short-term goal, or at times the *change* is completely absorbed and rendered compliant into the existing framework [52].

It is argued, therefore, that the liberal and radical theories of gender defining *women* in fixed ways actually work to decrease the effectiveness of intervention strategies as they cannot expand (or account for) ways women are expected to *be and do* engineering. This is, in part, why the voices of the successful, achieving women in engineering are by and large missing from much of the research informed by these theories of gender. Acknowledging this, opens the way to begin to think about why some women find some aspects of engineering attractive and some of the implications of this reality for advocacy. How can advocacy learn from these women and redefine powerful, confident, positive identities for women in engineering?

The recent shift in *gender and engineering education* research identifies the *masculine* and the *feminine* as constructed categories, which while being independent of maleness or femaleness, work to construct particular, masculine (in the main) engineering identities. Contemporary advocacy has begun to explore effective ways of working within/alongside the tensions created as engineering education crosses the boundaries (often, none to smoothly) between paradigms in response to external forces (eg sustainability, professional competencies). In this tension, advocacy can challenge the *rules* and *ways of doing* engineering, thereby creating space to begin the work of attempting to define the *new engineer* [7] and ways education can contribute to the [re]production of this engineer. Advocacy must continue to assume a key role in this redefinition of the *new engineer* to ensure there are increased opportunities for women to enjoy equitable and equal participation in engineering's future.

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BIOGRAPHY

Heather Stonyer works in the Faculty of Science and Engineering at the Auckland University of Technology in the position of Academic Staff Developer. The role combines her academic and professional interests in engineering (formerly mechanical engineer) and tertiary education. She has lead successful innovative teaching projects in SET which have included: teamwork capability development throughout a degree programme; research capability development in postgraduate programmes; integrating learning through engineering design; problem-based learning in VET; project based learning and thinking. Her work in advocacy in engineering is based in personal experience and postgraduate studies exploring the experience of women in engineering. Current research interests include: developing a model for curriculum change in SET at the tertiary level, implications and application of *the knowledge economy* for SET education, SET research capability development for staff and students.

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ENGINEERING EDUCATION FOR WOMEN IN BOTSWANA

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The enrolment of women in university engineering programmes in Botswana is very low compared to that of men, although current government policies on education allows for equal educational opportunities for both men and women. A study has been conducted on the female engineering students at the University of Botswana to look into this problematic situation. It was found that only 11.1% of the engineering students at the university were female with 66% between 21 and 25 years, 84.5% unmarried and 65% without children. Most of the women who were enrolled in engineering non-degree programmes were in certificate and ordinary diploma programmes. Percentage wise, however, the higher diploma programme had the highest percentage of female students. In the engineering degree programmes, civil engineering had the highest enrolment followed by electrical engineering. The majority were influenced in selecting engineering as their field of study by their interest in engineering, job opportunities in the engineering field, ability in mathematics and science, salary of engineers and ambition to assist in developing women's welfare in selecting engineering as their field of study. They felt engineering can be studied by both sexes. They perceived engineering as mathematical, practical and challenging and they all felt great and fulfilled by their choice. They revealed that they experienced some discrimination from male students and male lecturers. They felt institutional resources were inadequate. Some suggestions have been made on what to do to increase female participation in university engineering programmes in the country.

INTRODUCTION

The enrolment of women in university engineering programmes is much lower than that of men in both the developed and developing countries [1]. Studies in Ghana [1], Sierra Leone [2], South Africa [3], New Zealand [4], USA [5], Sweden [6] and Australia [4] confirm this

statement. This situation has created a worldwide concern about the enrolment of women in university engineering programmes.

Gender disparity in education in Botswana and many African countries seem to have been influenced by cultural practices. Although women are known to handle tough and strenuous jobs in Africa, there has been a belief that a man must earn salary and a woman must remain as a housewife resulting in women choosing or being made to choose less rewarding jobs, and studying courses predominantly known to be female areas of study [7]. Engineering is a course driven by mathematics and physics. It has been observed by Fennema et al [8] that there is limited participation in mathematics related occupations by women because many of them receive inadequate preparation in mathematics, and therefore are unable to enter educational programmes or careers that require mathematics. Many high school girls in Africa shy away from or stop studying mathematics acquiring minimum school graduation requirements and resulting in low female enrolment in engineering programmes [1]. Bhatia [9] has commented that most girls hesitate to go in for science, as this makes heavy demands, both in matters of time and effort, and thus depriving them of other interests and activities. Furthermore, with the additional duties traditionally expected from girls at home, they are discouraged from aspiring to study and research of pure sciences [9]. Zietsman and Naidoo [3] also confirmed that in South Africa girls are less interested in physics and mathematics than boys, and fewer choose to study them at school and university, which severely restricts their entrance into engineering. At a graduation ceremony at the University of California, Davis in the USA, women received 50% of bachelors degrees in the life sciences, 31% in computer and information sciences, and 30% in physical sciences but only 14% in engineering indicating the low enrolment of women in engineering programmes even in a developed country [10]. Studies in Ghana revealed a men to women ratio of 8:1 in the School of Engineering at the University of Science and Technology [1].

The Botswana Government educational policy provides equal opportunities for the enrolment of women in all fields of study in and outside the country, and demographically, women outnumber men in the country. Despite this, in the Faculty of Engineering and Technology and the Faculty of Agriculture, the two faculties with engineering programmes in the University of Botswana, which is the only university in the country, women are under represented in all the engineering programmes. The enrolment statistics in the University of Botswana shows that, the enrolment of women in certificate in engineering, diploma in engineering and bachelor of science degree in engineering programmes were 17%, 10% and 14% respectively in 1996/1997 academic year, 12%, 10% and 12% respectively in 1997/1998 academic year, 14%, 6% and 14% respectively in 1998/1999 academic year, and 9.4%, 10% and 13.7% respectively in 1999/2000 academic year [11]. The percentage enrolment classified by faculties from 1998/1999 to 1999/2000 academic years showed that the women enrolment at the Faculty of Engineering and Technology was the lowest at 10% and 11% respectively, followed by Faculty of Science at 28% and 26% respectively while, Faculties of Humanities, Education, Social Sciences and Business had a respective enrolment of 58% and 57% respectively, 57% and 55% respectively, 49.7% and 51% respectively, and 44% and 45% respectively [11]. Similarly at the Faculty of Agriculture, where diploma in agricultural engineering is offered, the 1998/1999 and 1999/2000 academic years enrolments showed that only 13% and 0%, respectively of the students who enrolled in the programme were women and the enrolments for the previous years were not any better.

There have not been any gender studies on engineering education done in Botswana. This study interviews certificate, diploma and bachelor degree students in the Faculty of Engineering and Technology and Faculty of Agriculture of the University of Botswana to establish the characteristics of female engineering students, factors motivating them to enrol in engineering, female students' perception of and problems faced in their programme of study and female students' perceptions of institutional resources. The study also tries to deduce the reasons for the low enrolment of women in the engineering programmes and makes suggestions for the improvement of women's participation in the programmes.

METHODOLOGY

A qualitative design approach was used for the study because of its exploratory nature, and data was collected through a three-part questionnaire. The first part had close ended questions relating to the student's personal characteristics and views, the second part had Likert scale ranging from 1 to 5 with 1 = strongly disagree, 2 = disagree, 3 = agree, 4 = strongly agree and 5 = very strongly agree, and the third part also had Likert scale ranging from 1 to 5 with 1 = very inadequate, 2 = inadequate, 3 = fairly adequate, 4 = adequate and 5 = very adequate. In the second and third parts, a mean of 3 separated agreement from disagreement and inadequate from fairly adequate respectively. The questionnaires were administered on all the seventy-one female students in certificate, diploma and bachelor degree in engineering programmes in the two faculties offering engineering programmes in the University of Botswana with 100% response. The data was analysed by the use of SAS computer programme. Descriptive statistics was used to report the findings. The results for the close-ended questions were interpreted in percentages, while the results for the Likert scale were interpreted in means.

RESULTS AND DISCUSSION

Student Statistics

Tables 1 and 2 display the enrolment statistics of the engineering non-degree and degree programmes respectively in the University of Botswana for the 1999/2000 academic year. Looking at numbers alone, most of the women were found to be enrolled in certificate and ordinary diploma, but percentages reveal that higher diploma had the highest percentage of women followed by certificate and ordinary diploma. Table 1 reveals, after simple calculation, that there were 11.1% and 7.3% women in the first and second years respectively in the certificate programme, 8.1% and 9.8% respectively for the ordinary diploma programme and 20% and 16.7% respectively for the higher diploma programme. Simple computation indicates that 9.7% females were enrolled in the engineering non-degree programmes. Table 2 shows that 21.1%, 11.8%, 13.3%, 5.9% and 13.2% women were enrolled in design and technology for the first, second, third and fourth years respectively. The corresponding findings for: civil engineering is 0%, 11.4%, 10.0%, 22.2% and 16.5% respectively; electrical engineering is 0%, 11.4%, 18.2%, 11.8% and 11.3% respectively; mechanical engineering is 25%, 15%, 15%, 35%, and 7% respectively; building engineering is 25%, 33.3% and 0% for the second, third and fourth years respectively, while numbers alone indicate the highest women representation in civil engineering followed by electrical engineering. Simple computation again reveals that 13.7% women were enrolled in the engineering degree

programmes. There were a total of 108 female students out of a total of 969 students (ie 11.1%) registered in engineering non-degree and degree programmes. This is a clear indication that women are very under-represented in the engineering programmes.

Table 1: Student distribution for engineering non-degree programs in 1999/2000.

Year of programme	Certificate		Diploma		Higher Diploma	
	Total	Female	Total	Female	Total	Female
1	153	17	173	14	20	4
2	124	9	133	13	24	4
TOTAL	277	26	306	27	44	8

Table 2: Student distribution for engineering degree programs in 1999/2000.

Year of programme	Des. & Tech.		Civil		Electrical		Mechanical		Building	
	Total	Female	Total	Female	Total	Female	Total	Female	Total	Female
1	19	4	9	0	15	0	12	2	-	-
2	17	2	32	6	35	4	20	1	4	1
3	15	2	20	2	22	4	18	1	6	2
4	17	1	36	8	34	4	30	3	8	0
TOTAL	68	9	97	16	106	12	53	7	18	3

Students Personal Characteristics

Majority (66%) of the students were in the age range of 21 to 25 years, 24% were between 26 and 31 years, 9% were below 20 years and only one student was above 31 years. Three percent were divorced, 12.5% were married, 84.5% were unmarried and none was widowed. Sixty five percent had no children, 28% had one child and 7% had more than one child. For comparison, studies in Ghana indicated 80% female students between 20 and 25 years, 10% between 26 and 30 years, 10% less than 20 years, 96% unmarried and none had children (Baryeh et al, 2000). Seventy two percent had Cambridge Overseas School Certificate (COSC) Ordinary at the time of enrolment in the university, which is the minimum qualification for enrolment. The rest had equivalent qualifications. The table also shows that majority (65%) of the students decided to study engineering at COSC Ordinary level, which is the latter part of their secondary school education, 15.5% at the Junior Secondary School stage and 11% after failing to secure places in other areas of interest. This agrees with studies in Ghana where majority (84%) of the students studied took the decision to study engineering during the latter part of their secondary school education [1]. The percentage in Ghana was higher than the one in Botswana because in Ghana this was during the General Certificate of Education (GCE) Advanced level when students are more mature than at the Ordinary level, agreeing with Ginsgerg's [12] and Grewal's [13] assertion that the choice of career is best made with maturity of individuals. It is surprising that 11% chose to study engineering after failing to secure places in other areas of interest, because in most cases students still choose other non-engineering fields when they fail to secure places in an engineering field. This indicates that some women who qualify to study engineering decide to go into a non-engineering field due to lack of interest in engineering. Forty five percent had an

objective to study engineering in order to become engineering practitioners, 42% wanted to work in other government institutions, 5.5% wanted to become engineering teachers, and 5.5% had no objective. Studies in Ghana showed that none of the students wanted to be teachers due to the low salaries of teachers [1].

Influencing Factors

Table 3 is developed from answers to questions with Likert scale ranging from 1 to 5. A mean of 3 separates the influencing factors from the non-influencing ones.

Table 3: Factors influencing female students to enrol in engineering programmes.

Response item	Mean	SD
Interest in engineering	4.1	0.9
Job opportunities in engineering field	3.7	1.1
Ability in mathematics and science	3.6	0.8
Salary of engineers	3.3	1.1
Assist in developing women welfare	3.2	1.2
Parental advice	2.7	1.0
The community	2.7	1.0
The school guidance counsellor	2.6	1.2
Science teachers' advice	2.5	1.0
Friends	2.4	1.0
Lack of any advice	1.5	0.9

The table indicates that the students were influenced to enrol in the engineering programmes by their interest in engineering (Mean = 4.1), job opportunities in the engineering field (Mean = 3.7), ability in mathematics and science (Mean = 3.6), salary of engineers (Mean = 3.3) and their desire to assist in developing women's welfare (Mean = 3.2). The remaining factors in the table with means less than 3 had no influence on their decisions. This is similar to findings in Ghana [1] and New Zealand ([4], [14]) where it was found that the decision to study engineering was in most cases prompted by students' natural interest in engineering and the high mathematics and science abilities. Newton [15] and Granstam [16], however, have reported that the decision to study engineering for young women overseas, follows a recognised ability in areas such as mathematics, physics and chemistry rather than a long held ambition to be an engineer. Amarteifio [2] also found that women who went into engineering in Sierra Leone did so mainly because they were good in science and mathematics. In Botswana, however, this study has shown that the main motivating factor is students' interest in engineering with ability in mathematics and science being a third major influencing factor. The results therefore conform to the statement that a person's likes and dislikes, perceptions on his or her abilities, interests and values influence his or her choice of occupation (Date-Bah [17], Rice [18], Ginzberg [12]). Ginzberg [12] has indicated that the final choice of occupations are compromises between interest, values, opportunities and limitations in the real world. Naizer [19] has further indicated that students' entry into and retention in the scientific talent pool, is a result of interest and abilities in science and mathematics. When parental advice, the community, guidance counsellor and science teacher

were put together and classified as motivating factor from people, this composite factor became the second most influencing factor after interest in engineering. Studies in Ghana has revealed that this composite factor had a higher influence on students' choice than any other factor considered. Parental influence on children's career have also been reported by Rice [18] and Amissah [20]. Granstam and Sani [6] noted in studies in Sweden that 56% and 25% of the female engineering students studied, had fathers who were engineers and brothers who were studying engineering respectively, and Godfrey [4], in a study in New Zealand, found that 50% of the female engineering students studied, had a family member or close friend who was an engineer. Career choices, according to Osipow [21] and Naizer (1993), are a reflection of strong identification with the father. Rice [18]also identified parents, peers, school personnel, intelligence, aptitude, interest, job reward/satisfaction, prestige, sex role concepts as some of the factors influencing occupational choice. Although parents had some influence on the students' choice, none of them had a parent or close relative who was in an engineering field. The fact that there were no significant influence from the school counsellors in their secondary schools, gives an impression that secondary school students receive very little information about the engineering profession. This partly accounts for the low enrolment of women in engineering at the University of Botswana.

Fifty six percent of the students indicated that they had women role models, while 44% indicated that they had no women role models. Those with role models confirmed that these people encouraged and influenced them. A number of studies have shown that women role models have high influence on career choice of women (Baryeh et al [1], Godfrey [4], McWilliams [14], Brown [22]. In Ghana, the presence of female engineering lecturers as role models encouraged students to work harder (Baryeh et al, 2000). According to studies by Godfrey (1991) and McWilliams (1991), female students in New Zealand liked to have more women tutors. Brown (1991) has also reported the significant improvement in female enrolment in science and engineering in some American universities as a result of attending seminars given by women role models.

Personal Assessment Of Engineering Profession Before Enrolment

Before enrolment, 59% felt that engineering is suitable for anybody who has the qualifications to study the programme regardless of gender, while 25% thought engineering is for extra intelligent people. Over half of them agreed that engineering was for *above average* students. Only 6% felt engineering was for men, 4% regarded engineering as dirty and 6% had no idea. After enrolment, 72% felt their perceptions depended on the engineering discipline chosen by them. Those in civil engineering said engineering had good job opportunities, while those in electrical engineering said women can handle engineering mainly because they were in light current electricity which did not demand much physical abilities. Those in agricultural engineering, mechanical engineering and building engineering indicated that sometimes it required physical ability, and those in design and technology felt engineering is interesting and creative. At this stage 13% found it hard to cope, 11% still felt one has to be highly intelligent to study engineering, 3% still considered engineering as harsh and dirty, and 1% classified engineering as boring and unfashionable.

Thirty two and a half percent revealed they were discriminated against by male students and lecturers, 42% felt the practicals were strenuous and 25.5% indicated that the mathematics was too much. This is unlike results in Ghana, New Zealand and Sweden where

female students did not experience any discrimination and did not complain about the mathematics in the programme (Baryeh [1], Godfrey [4], McWilliams [14], Gramstam and Sani [6]. Seven percent out of those complaining about discrimination revealed further that the men were given more and better attention than the women. This again is contrary to findings in Ghana and New Zealand (Baryeh et al [1], Godfrey [4], McWilliams[14].

Seven percent of the students felt threatened and insecure due to the male dominance of the field and some of the discriminatory experiences they were faced with. Twenty four percent indicated that the programmes were great and fulfilling, while 69% said they were highly challenging. Sixty seven percent felt their counterparts accepted them, 30% felt their counterparts looked down upon them and 1% indicated being maltreated by fellow male students.

Student Perceptions Of Institutional Resources

According to table 4, students indicated that all institutional resources for the engineering programs were inadequate.

Table 4: Students' perceptions of institutional resources.

RESPONSE ITEM	MEAN	SD
lecture hours	2.8	0.8
theoretical instruction in engineering	2.7	0.8
communication skills	2.6	0.8
computer skills	2.5	0.9
classroom facilities	2.5	0.9
stationary	2.4	0.8
time for study	2.4	0.9
practical instruction given by lecturers	2.3	0.9
technical preparation in engineering subject matter	2.3	0.7
library facilities	2.2	0.8
laboratory facilities	2.2	0.8
audio visual facilities	2.1	0.9
practical hours	2.1	0.9
workshop equipment	2.1	1.0
text books	2.1	0.8

The responses lie between inadequate and just below fairly adequate according to the Likert scale of 1 to 5. They felt sometimes there were too many students assigned to one equipment during laboratory classes, making it difficult for everybody to have a hands on experience. In such a case they felt the men gained from these classes more than the women because some of them used their natural physique to their advantage. They need more equipment, more contact hours especially tutorial hours, more classroom, library, laboratory and audio-visual facilities, more communication skills, books, stationery and study time. Some also revealed that they needed more industrial visits and group project works. This finding is very important for the university management to use in providing adequate resources for the engineering programmes. The inadequacy of university resources may cause women to loose

interest and switch to non-engineering programmes and even discourage other women who wish to study engineering from embarking upon it.

REASONS FOR THE LOW ENROLMENT

From the study it can be deduced that some of the reasons for the low enrolment of women in the engineering programmes are as follows:

1. Lack of information on engineering education
2. Inadequate counselling in secondary schools
3. Male chauvinism
4. Absence of plenty of female role models and absence of seminars given by female role models
5. Traditional roles society places on women
6. Women's lack of interest and subsequently lower performance in mathematics and science
7. The thought that engineering is for *above average* students
8. Possible fear of entering a male dominated field
9. Lack of interest in engineering

SUGGESTIONS TO IMPROVE OF WOMENS' PARTICIPATION

From the study the following are suggested for the government, the community, the university authorities and secondary school authorities to note and execute in order to improve the participation of women in engineering programmes in Botswana. These may also be applicable to other developing nations.

1. Career counselling must start early in the students school life and gender disparity must not be pronounced as far as choices and likes of the subjects are concerned. They must also be educated on the engineering career in secondary schools.
2. The study revealed that Botswana men are still very traditional and chauvinists. The men and the public at large need to be educated through the media about gender and the acceptance of women as equals. They need to be encouraged to make women feel at ease in male dominated fields.
3. Successful women engineers must act as role models and they should be invited to schools more often to instil the relevance of engineering in women's lives to secondary school girls, and give seminars and talks on women and engineering. Women at work in technical and engineering fields may be shown at these seminars using audio-visual equipment, and students should be made aware of how engineering can change their lives.
4. University engineering lecturers and students must be educated to accept female students and refrain from discriminating against them.
5. The Government must offer incentives to women who want to study engineering.
6. Girls must be encouraged at an early age to develop a liking for mathematics and science. Primary school girls may be exposed to science and technology with audio visual aids, and secondary school girls may be taken on industrial visits.
7. Special mathematics and science programmes may be offered to girls during the long vacation. At this time, girls may be introduced to hobbies in mathematics, science and

technology including dismantling and assembling of appliances and equipment to stir up their interest in engineering.

8. Examples in mathematics and science classes must involve the use of female interests and everyday life in the context of girls and society.
9. Men and women must do domestic chores together to enable the women to save some time for studies.
10. Girls must be given extra lessons in mathematics and science in primary and secondary schools to elevate their abilities in these subjects.
11. Women must be encouraged to recognise their potentials
12. Further studies should be conducted to investigate the reasons why university non-engineering women students do not enrol in university engineering programmes in order to use their reasons to improve women's participation in engineering.

CONCLUSION

The study has revealed that Botswana women are woefully under-represented in the university engineering programmes compared to men despite their high demographic percentage. This situation is due to lack of counselling and information on engineering, traditionality and chauvinism of men, difficulties in understanding scientific and mathematical concepts, absence of women role models, discouragement from people, among others. It was revealed that the main factor influencing women to choose to study engineering is their interest in engineering, followed by job opportunities in the engineering field, ability in mathematics and science, the salary of engineers, and the desire to assist in developing women's welfare. Parental advice, the community, school counsellor, science teachers and friends, standing on their own, influenced them less. When these were put together, however, as people's influence, this composite factor became the second most influencing one. The students judged institutional resources as inadequate. Some suggestions have been made to motivate more women in Botswana to enter the engineering field.

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PRIORITIES FOR THE NEW ENGINEERING EDUCATION MOVEMENT IN SOUTH AFRICA

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As South Africa's new democracy develops and grapples with issues of social and economic transformation, academic staff responsible for education of the next generation of engineers will find that it is not enough simply to prepare and deliver lectures. There are the beginnings of an engineering education movement in the country attracting increasing numbers of committed educationalists. The paper argues that this movement will need to have a focus and set of priorities if it is to be effective and outlines what such a set of priorities might look like.

INTRODUCTION

The South African engineering education system is a relatively small one with eight universities and thirteen technikons offering qualifications in engineering. The engineering education movement in South Africa is young with the Centre for Research in Engineering Education (CREE), established in 1995, playing a key role in establishing a national network and organising the first two national conferences on engineering education in 1997 and 2000. There are the beginnings of systematic collective action by educators in our region with the formation of a task team to establish a society for engineering educators. What should be the focus of such collective action and how should that focus translate itself into change in Faculties and departments?

KEEPING PACE WITH CHANGE

Many of our faculties and departments are places where cutting edge research is conducted in key areas of technology and knowledge production. In their capacity as engineering researchers our colleagues know about having to keep pace with change, albeit primarily in the area of technology, and yet most do not recognise that same need when it comes to changes on the educational front.

Throughout the world one finds a re-examination of the purpose and effectiveness of teaching and learning in higher education. Research into new approaches to curriculum, in methods of delivery and in our understanding of how students learn, fill the proceedings of international conferences, workshops and publications on higher education in general, and engineering education in particular.

What has shaken the complacency of the engineering professors who just two decades ago were quite content with the lecture theatre and chalkboard environment that defined the parameters of their teaching?

The main cause is the global re-think of what it means to be an engineer. Industry no longer wants engineers schooled in narrow technical disciplines with a limited range of knowledge and skills. Employers and professional associations are more interested in students' abilities when they graduate than in the content of their studies. Firms are becoming more multi-disciplinary and need graduates who have the ability to learn whatever it takes to do the job required of them. As a result the purpose of the undergraduate qualification is being reviewed. . This review has taken shape in the form of the shift to outcomes-based accreditation procedures adopted by several national engineering accreditation authorities in the Washington Accord [1], an international agreement working towards mutual recognition of undergraduate engineering qualifications.

However, the key development in South Africa necessitating a fundamental review of the old ways of doing things has been the attainment of democracy and with it an end to racial restrictions on access to engineering education and the challenge of building a sound economy. As a result we have seen dramatic changes in the social and educational profile of students entering tertiary institutions. A National Qualifications Framework based on outcomes is being developed to, amongst other things, create a rational coherent system with multiple avenues for the recognition and advancement of skills and education for the majority of South Africans who were excluded from the former higher and further education and training system.

In 1998 the Engineering Council of South Africa (ECSA) adopted an outcomes-based framework for the accreditation of university engineering programmes in response to both these local and global developments.

A SET OF PRIORITIES

It is not enough to simply recognise all these changes and encourage individual academics to do their best under the circumstances. The engineering education movement in South Africa needs to have a plan and a set of priorities if it wants to be able to gain access to resources and gain recognition for time spent on developing educational programmes. A possible set of priorities is outlined below.

Prioritise Our Educational Programmes

It makes sense to prioritise the one thing that ensures our jobs as academics – a healthy and effective set of educational programmes producing reasonable numbers of suitably qualified graduates within a reasonable period of time. To do this means choosing between the demands of research, administration and teaching. Most engineering faculties have not experienced the current wave of retrenchments threatening academics in higher education in

[1] Australia, Canada, Hong Kong, Ireland, New Zealand, South Africa, UK, USA.

South Africa, mainly because we are seen as a key sector in the stimulation of economic growth. But the number of engineering applicants is dropping and graduation rates are not as high as we would wish. Student fees and government subsidies based on student numbers and success rates pay our salaries. Dropping student numbers and declining pass rates means a frozen post now, a retrenchment later, which means, in turn more work all round.

Move From Academic Support To Academic Development

We need to accept the challenge of producing engineers from the pool of school leavers who apply to our institutions each year and stop complaining about how badly the schooling system does its job. We are privileged to work with the brightest school leavers in the country whatever inadequacies we suspect there might be in their educational backgrounds. Our job is to provide them with the best possible educational opportunities of becoming engineers.

Our first efforts, 14 years ago when the racial restrictions were lifted, focused on trying to *fix the gaps* of students from disadvantaged educational backgrounds entering our historically white institutions. We relied on academic support tutorials and *bridging* courses to prepare these students for what we had always done – and we carried on in the same old way. Many of these support programmes served a limited number of students and had only a marginal effect on the overall graduation rates of our institutions.

We have learnt that rather than just trying to change the students to fit into our programmes we also need to change our programmes and the learning environment to better match the students we work with. We need an academic development approach which looks for ways to embrace the diversity of our students and reshape our curriculum and our skills to ensure that best fit.

Prepare Students for Change by Embracing Change Ourselves.

If there is one thing we need to be able to help our students develop it is the ability to cope with change. Our institutions are learning laboratories – students learn from everything they encounter including the behaviour and attitude of the teaching staff. In helping students develop the necessary skills for their roles as professionals in a dynamic and ever-changing world, we need to look at what sort of role models we provide.

As an example consider how many of our colleagues are responding to the change in educational focus to outcomes. Many have adopted an attitude of *let's ignore it until someone forces us to do something and then let's try and get away with the doing as little as possible* [1]. Is it any surprise that we often see that same attitude displayed by our students in relation to work we set in our courses and programmes?

Exploit the Opportunities in the Shift to Outcomes-based Education

The change in the ECSA accreditation process to one based on programme outcomes opens up some very important possibilities.

- It has brought key educational issues, namely the relationship between learning objectives, the learning process and assessment, to the fore for discussion in engineering departments.

- It allows much greater freedom for programmes to define their own content as the emphasis has shifted from what students know to how students can use what they know.
- It is focussing attention on how we assess our students.
- It requires that our programmes have in place systems of continuous evaluation and improvement, a healthy change from the ad-hoc approach that we currently depend on, and one that will force us to apply in our educational design the same principles that we teach our students to adopt in their engineering design.

Let Educational Research Inform Our Practice

During the past two to three decades substantial progress has been made in research on how students learn in higher education. Much of this work has been published in an accessible form [2,3]. We need to ensure that we keep in touch with these developments and help, in particular, new members of staff gain access to this information. Furthermore we need to incorporate this new knowledge into our practice.

We can also add to the pool of understanding that is growing in higher education by conducting our own research in our contexts. We need to collect information and evaluate our educational programmes, as we would expect our students to do with an engineering assignment, so that we can identify problems that need attention rather than relying on tea-room anecdotes to inform departmental decisions on curriculum and course design.

Develop our role in South Africa's transformation

Although engineering and engineering lecturing have become global activities with job opportunities crossing national boundaries, as teaching staff we need to recognise the limitations, possibilities and responsibilities placed on us by the local socio-political situation.

South Africa is in the midst of a process of social transformation that is attempting to undo decades of social, educational and economic damage. The community at large regards education, particularly higher education, as one of the key elements for ensuring our country's ability to overcome the problems of economic underdevelopment, poverty and unemployment.

Our faculties bear the responsibility for producing the engineers that are needed to play a key role in the economic development of our country. That is what the taxpayers pay us to do and that is what we will increasingly be asked to account for.

Remove gender barriers – real and perceived

As the entry point to a profession that has been historically been limited to males we have an added responsibility to help facilitate the increased participation of women in engineering in line with the broader project to bring about social equity. We are witnessing increasing numbers young African women enrolling to study engineering in South Africa. Our research reveals that a significant number of these students appear to be motivated by the opening up of new opportunities to serve their communities, and to prove themselves in a career traditionally dominated by white males [4].

How do we as educators build on that motivation and help these individuals fulfil their dreams? Often we expect students to overcome all the hurdles we place for them but we omit to ensure that in the process their source of internal motivation is sustained.

Experience elsewhere (outside of the previous Eastern Block countries) indicates that efforts to attract women into engineering seem not to be able to get beyond a 20% participation ceiling. Societal gender stereotyping, particularly in the home and at school, and the overwhelmingly male culture of the engineering profession appear to be insurmountable obstacles in the way.

I want to suggest that in the current South African context, with the recent opening up of career opportunities to all races, societal pressures against young African women choosing engineering as a career are relatively weak. We may have a few years before that changes and in that time we need to find ways to encourage large numbers of African women into the career and support them as they help to transform the profession.

CONCLUSION

Producing engineering graduates with the basic abilities required to enter the engineering profession and the commitment to help steer the development of a country like South Africa is not a straightforward task. It requires much more than simply preparing and delivering lectures. The challenges facing the educators of future generations of engineers in South Africa demand an engineering education movement with a plan and a set of priorities.

As participants in that movement we need to serve as role models for our students, approaching this task as we would except them to approach any open ended engineering problem - systematically, using all the information and resources at our disposal and mindful of changing constraints. In the process we need to keep abreast of and contribute to developments in higher education in general and engineering education in particular.

Until we get it right, the goal of sustainable economic growth, full employment and prosperity will remain out of reach for the majority of South Africans.

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BIOGRAPHY

Jeff Jawitz is the Educational Development Officer at the University of Cape Town in South Africa. He is a founder member of the Centre for Research in Engineering Education and edits the centre's magazine *For Engineering Educators.* His recent research has focussed on curriculum development and women in engineering. He is active in finding ways of improving student learning and staff teaching in the face of increasingly diverse classes of students and regularly runs curriculum development and staff development workshops.

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DEVELOPMENT OF A LEARNER-FOCUSSED, SUSTAINABLE-ENGINEERING SUBJECT

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This paper looks at how the subject content, teaching method, and assessment techniques in an energy engineering subject were aligned to promote students' understanding of sustainability and to develop the graduate capabilities expected of reflective practitioners. The subject was structured as a *Learning Organization* [1], which emphasised student collaboration, negotiation and responsibility for learning. Student-focused learning and teaching methods were used to facilitate deep approaches to students' team learning and skill development.

Combined face-to-face, web site and online discussion facilities were developed to provide an interactive learning environment where students learn in teams. Students demonstrate the quality of their understanding of the multidisciplinary nature of this subject through making links between theories of the subject and practice using self-selected case study projects which are developed throughout the semester. The case studies require them to develop their skills in critical reflection, analysis, synthesis, integration, creation and the application of ideas. Students are encouraged to be more pro-active and to consider economic, environmental, political and social factors in their technical decisions. The paper discusses ways in which we have examined the effectiveness of this approach by interviewing students, and analysing their reflective portfolios, case study reports, and feedback surveys. It therefore draws out the wider implications for extending student-focused-teaching and learning to all engineering subjects, including those offered by online delivery.

INTRODUCTION

The desire for a sustainable new millennium in the context of rapid global change has prompted rethinking about how university education can act as a catalyst for change. Universities increasingly have a social obligation to promote sustainability goals and

encourage their staff and students' commitment and capacity to develop a sustainable environment. To meet the challenge of leading a rapidly changing integrated global community with changing social values and expectations, our graduates need to be lifelong learners who are sensitive to community needs, and have a proactive attitude towards developing team working and life long learning skills, reflective practice, and leadership in the society. Engineering education is increasingly being developed as a focal point for leading and addressing the needs of society. Significant cultural change is taking place within university Engineering Faculties, where student-focused-teaching and learning, and sustainability-based value systems are increasingly being asserted online.

UNDERSTSANDING SUSTAINABILITY AS A DESIRED GRADUATE ATTRIBUTE IN ENGINEERING EDUCATION

Georg [2] defines sustainability as the *triple bottom line of economic prosperity, environmental quality and social justice* which acts as the benchmark by which all engineering activities are being measured. Agenda 21 of the United Nations at the Earth Summit in Rio addressed the important role of engineers and decision-makers in achieving sustainability through global partnership. The implementation of the Agenda demands a new kind of engineering graduates who are proactive community leader, and embrace and integrate technological, economic, social and environmental objectives to achieve sustainability and to avoid deepening economic divisions with continuing deterioration of ecosystems on which life on earth depends. This agenda is also reflected in global pressures for change in engineering education.

In the United States, backed by social demands, the American Society for Engineering Education called for a cultural change in engineering education [3]. The Board of Engineering Education of the National Research Council [4] recommended that engineering schools align the faculty reward system more fully with the total mission and the purpose of their institutions. To address social needs in Canada, the Canadian Academy of Engineering [5] recommended broader, more integrated undergraduate programs with an increased emphasis on design and social context. In Britain, Broers [6] recommended extracurricular activities to develop communication and leadership skills in undergraduate engineering students.

Similarly in Australia, engineering education has been the subject of a number of reviews over the past decade. Skillington [7] analysed engineering education and recommended an improvement in the quality of four-year engineering graduates through more focussing on students learning to maintain equivalence with world standards. Bates *et al* [8] suggested the need for a more appropriate balance between technology and non-technology skills, acceleration of the broadening of undergraduate engineering courses, and the development of cross-discipline and interpersonal skills in undergraduate education. Hall [9] reported on the disturbing state of teaching and research equipment in mechanical engineering departments around Australia, and warned that if the situation continued, graduates and future engineering leaders would not be able to compete with overseas competitors. The Institution of Engineers, Australia IEAust Code of Ethics calls for the promotion of sustainability principles and ethics by the members. The IEAust also developed a handbook [10] to guide engineers to incorporate sustainability requirements into their professional practice.

The cultural changes in Australian Universities are further enhanced by adoption of many of the recommendations of the IEAust National Review of Engineering Education [11].

At the University of Technology, Sydney (UTS), they have been applied through establishing the Institute for Sustainable Futures (ISF) to promote sustainable futures through research, consultancy and training. The IFS defines sustainability as a dynamic process in which the economy, environment and social equity are linked in decision making. UTS's commitment to sustainability and social fairness was formalised in November 1998 when the institution signed the Tallories Declaration, representing an alignment with the global universities who have committed to creating a just and sustainable future [12].

The Faculty of Engineering, at UTS was restructured and a process of re-evaluation of values and missions took place. Sustainable development and life cycle analysis were incorporated as key elements in the newly developed broader undergraduate engineering courses which also consider environmental, social and economic impact analysis of technical decisions made. The Faculty restructured, to address the cultural changes and to promote practice-based, learner-focused teaching and learning curriculum, and sustainability principles as a desired value system [13]. Sustainability became the foundation idea in the new curriculum, a basic ethic, and the fundamental rationale for education. Generic graduate professional and personal capabilities such as critical thinking, interpersonal and communication skills, and reflective practice are also incorporated in the course design to enable engineering graduates to be reflective practitioners with capabilities to analyse, synthesis, create, and apply knowledge. The UTS Faculty of Engineering won the 1998 IEAust Award for Cultural Change in Engineering Education.

The promotion of sustainability as a desired value system in engineering courses requires action for change at all levels, especially by academic staff in the development of new subjects. All these recommendations, reviews, achievement and expectations, place enormous pressure and responsibilities on engineering educators to provide quality technical and non technical learning, and to develop required skills and value systems.

The aim of this paper is to highlight progress towards addressing desirable cultural changes in engineering education and establishing student-focused learning patterns and processes in the development of an engineering subject. The subject's development was influenced by a combination of global, national professional, institutional and moral factors which together set the educational standards for the subject.

A REFLECTIVE APPROACH FOR DEVELOPING THE SUBJECT AND IMPROVED TEACHING

We believe enhanced learning is more likely to occur in subjects which are designed using a student-focused approach, where the emphasis is on creating an environment which facilitates learning [14][15][16][17]. Student focused teaching includes taking students' prior ways of experiencing the subject into account, engaging them in experiences which challenge and change their understandings, and putting a greater emphasis on what students do in order to learn [18]. Teaching and learning are seen as two sides of a coin, in which teaching methods, student learning, subject materials and assessment need to be linked to address learning objectives [19].

Our understanding of teaching is also expressed in a similar way to that of Bruner [20]:

> *We teach a subject not to produce little living libraries on that subject, but rather to get a student to think mathematically for himself, to consider matters as an*

historian does, to take part in the process of knowledge-getting. Knowing is a process, not a product.

Improving teaching as an integral part of this approach involves improving the teachers' understanding of students' learning in the subject. Studies by Hargreaves, Woodruff and Wallis have indicated that mechanical engineering students in Australia adopted a surface approach to learning as they progressed through their courses [21][22]. This creates a challenge for staff who seek to encourage a deep approach. When students pass a subject through surface approaches to learning at early stage, it is hard to discourage them from repeating the process in similar situations at later stages of their course. Students' conceptions of learning also vary from learning as an increase in knowledge, and learning as memorising through to learning as changing as a person [23]. In engineering subjects, we need students to be capable of engaging in learning as abstraction of meaning, understanding of fundamental principles and concepts, which can be applied to both familiar and unfamiliar real cases, and ultimately changing student views, behaviour, and performance. This highlights the fact that the key for improved learning lies in students' conceptions, perceptions and ownership of learning. Often this means we need to change the conceptions of learning that students perceive to be required by our subjects. As stated by Marton and Ramsden [24] *learning should be seen as a qualitative change in a person's way of seeing, experiencing, understanding, conceptualising something in the real world rather than as a quantitative change in the amount of knowledge someone possesses*. Changing prior learning perceptions and cultures require continuous efforts, in collaboration and partnership with other staff and students. To encourage these conceptual changes, engineering subjects are increasingly emphasising opportunities for students to explicitly reflect on their own learning of the subject, compare their understandings with others, engage in collaborative learning with peers and test out new ways of understanding in real world situations.

The next section of the paper describes the design of the Energy Conversion subject, which explicitly aimed to develop students' understanding of sustainability in energy engineering, and which incorporated student focused learning approaches. Following this, we present findings from the subject evaluation, then recommendations for others seeking to develop similar approaches.

DESIGN OF THE ENERGY CONVERSION SUBJECT

Energy Conversion is a postgraduate subject covering many disciplines with rapidly changing knowledge bases. The area is affected by social and political decisions and governmental regulations. These make it controversial and difficult to learn. Our main goal was to help students to understand the basic design of renewable, non-renewable, and alternative energy conversion systems, in the context of relevant environmental, economic, social, and technological factors. This subject undoubtedly generates some controversy as different factors are quantified and valued differently by different people in different setting. For example, nuclear power generation may offer advantages in relation to global warming but factors such as social acceptance can play tremendous impacts on developments and application of this energy system. Students need to learn to think critically about the relationships between these complex and interdependent factors in order to make informed professional judgements. Within the Energy Conversion subject students were encouraged to learn the fundamentals of a sustainable energy conversion system, and to develop reflective

skills to recognize conditions which a system is sustainable when social, economic, environmental, and technological factors are taken into account appropriately. The objective of the subject also was for students to work in groups to co-create a common understanding of the quality standards in the selection and promoting of a sustainable energy system.

Encouraging high quality student learning involves all aspects of developing, monitoring, assessing and improving the effectiveness of the curriculum, teaching methods, and assessment. The re-design of the subject emphasised alignment between subject objectives, teaching and learning activities and assessment [18][25]. In order to promote collaborative learning between students and encourage reflection on learning, the subject structure was based on *Learning Organization* where students learned in teams and took more responsibility for making decisions about their own learning. As stated by Senge [26]

> *As the world becomes more interconnected and business becomes more complex and more dynamic, work must become more learningful. It is no longer sufficient to have one person learning for the organization and have everyone else following the orders of the grand strategist. The organizations that will truly excel in the future will be the organizations that discover how to tap people's commitment and capacity to learn at all levels in an organization.*

A team case-study project-based approach was developed, to engage students in a simulated real-world experience. Real-world experience was perceived to be important for students' professional development as Engineers, and for encouraging students' perceptions of subject relevance. The important role of case-study based learning is derived from the students' own control of their learning, from identification of the problem, planning the process of investigation, evaluation of alternative solutions, regular progress reports which lasts the whole semester, and finally concluding the project on time. Our views on effectiveness of case study based learning were also shared by a panel of independent national and international reviewers, evaluated the 20 years project-based engineering education in Aalborg University, Denmark Tkjersdam [27]. They concluded that the graduates are more readily adaptable, with strong qualities in the field of problem shooting, cooperation, communication and synthesising project work.

To make students' achievement of the learning objectives possible, a wide variety of teaching and learning experiences were linked to case study based assessment approaches. The subject included three-hour face-to-face interactive classes and use of a subject web-site and the *TopClass* course management environment. We developed and tried student-focused learning strategies through facilitating group discussions both in class and online, emphasising the creation of an environment of collaborative team learning and reflection amongst the students. Table I shows the relation between learning objectives, teaching and learning activities and assessment in the subject.

In the first hour of the face-to face classes, brief lectures provided some reference information on the impacts of energy related decisions and actions on society and environments, as well as some appreciation of the important role of non-technological factors and interest groups in shaping the development of energy technologies. The lecture focused on developing students' understanding of key aspects of the subject, selected from a large body of multidisciplinary technical information. Presentation by the lecturer was interspersed with buzz group discussions and followed by students' active reflection on their own learning in a portfolio. The rest of the class time was allocated for team learning, presenting, assessing and reflecting on student-selected case study projects.

Students were encouraged to engage in scholarly team activities online, using the *TopClass* course management system. Students' individual weekly progress reports were submitted in *TopClass* to be reviewed and commented by other students. The reports were judged on the level of intellectual and imaginative powers, soundness, understanding, judgement, problem solving skills, ability to communicate and market/justify solutions and the ability to find relationships between what students have learned and to predict what will happen in future.

ASSESSMENT MECHANISMS

Students' perceptions of assessment requirements are strongly related to their approaches to learning and learning outcomes [14][18][19][25]. Students focus on assessment requirements, so subjects which seek to develop students' graduate attributes must show how these are related to success in assessment tasks. Assessment approaches in this subject were aligned with the learning objectives for the subject, following the principles suggested by Biggs [18][25]. Table I shows the selected assessment tasks which guided and enhanced student learning, including a progressive case study, reflective journal and final examination. A critical process, which in many ways underpinned our whole approach, was the integration of critical reflection and the development of academic and professional attributes into the portfolio and case study. Self-assessment, peer, assessment, group assessment, class assessment, and lecturer assessment were a variety of approaches for assessment and feedback.

The case study projects where designed to be original, innovative, and individual, and were developed progressively over the semester. They focused on integrating the development of students' understanding of sustainable energy systems with the development of a range of professional and personal graduate attributes. Although the case studies were submitted by individuals, the process of developing them involved students in scholarly team activities including discovery, co-creation, analysis, synthesis, integration, and application of knowledges, taking into account the technological, environmental, economic, political, and social factors in their decisions. Students were formed into teams of four to five members. Each week, individual students prepared progress reports, which were presented orally and in writing to their team members for peer feedback. Academic reading and writing, and making the connections between the two, are complex processes which students were expected to demonstrate, drawing coherent conclusions from all of the sources. Feedback used to further improve their developing case study. The report was expected to identify energy problems from a number of different perspectives, to analyse, to gather evidence, to synthesise and come up with imaginative suggestions and short term/medium term/and long term recommendations. The report was judged on the level of intellectual and imaginative powers, soundness, understanding, judgement, problem solving skills, ability to communicate and market/justify solutions and the ability to find relationships between what students have learned and to predict what will happen in future. The final semester examination focused on assessing students' understanding of the basic design and analysis of energy conversion systems, drawing on understandings that were developed throughout the case study process.

The reflective portfolio was used to encourage students to identify their own strengths and weaknesses, to reflect on their own performance and learning, to take notice of the feedback they received, to be systematic in using this information, and to make a commitment to attend to these issues in future tasks.

We recognised that it was challenging to assess portfolio and case study reports on the quality of the written work. Quality standards (assessment criteria) for assessing the quality of students' learning and skill development from the reports and case studies were developed in consultation with students. To develop these quality standards, students were encouraged to reflect on the qualities of scholarly works as identified in literature [28]. The list of criteria is given in Table II. Self-grading and assessment were used to develop a capacity in students to judge the adequacy of their work in meeting the standards. Students were invited to make judgments about the extent to which they met those criteria and standards and email their self-assessment form to us or post it on TopClass for further group discussions. The application of standards is a task which involves considerable critical thinking and the ability to select and interpret criteria in ways which allow them to be applied to the case study. Discussions in class and online assisted students were assisted in this process.

Regular feedback on student activities, as a central feature of learning, facilitated effective and deep learning, encouraged understanding, integration, and application of ideas in the self-selected case study, and supported their development as self-directed, lifelong, independent reflective engineers. Regular progress reports on case study projects were used to guide and promote student progress towards achieving learning goals. Timely, structured, consistent and informative feedback, and suggestions about techniques to improve student performance were provided from a range of sources (self, peers, group, and lecturer).

Developing students' ability to assess their own work is an essential skill for lifelong learning, and a desirable component of student-focused-teaching and learning. Self-assessment played an important role in encouraging student deep learning in this subject. Throughout the case study process, students were encouraged to develop the ability to be realistic judges of their own performance and to monitor their own learning effectively. Students were asked to identify what needed be learned, compare it with what was known, and apply this approach in the case study. The progressive nature of the case study allowed students to recognize how they were addressing the various elements of the assessment criteria (eg evidence of originality, critical review of existing literature, knowledge creation, integration and application, development, selection of an appropriate approach from analysis and evaluation of alternative solutions). The portfolio was an indication of students' capacity to reflect on and assess their own work.

SUBJECT EVALUATION

Our evaluation of the learner-focused approaches in teaching energy conversion was done to see how the new design of the subject was perceived by students and to improved the subject where necessary, in order to improve the learning outcomes for students. Multiple evaluation methods were triangulated to indicate the effectiveness of the approach in assisting and enhancing student learning. These included:

- Analysis of students' assessment responses. Student portfolios provided information about what students had learned and their capacity to reflect on their own learning. Students' case study reports provided information about their understanding of key aspects of the subject and their ability to apply their understandings in a realistic setting.
- Student surveys, to assess students' perception of different aspects of the subject.

- Student interviews, focused on students' perceptions on what they had learned and what aspects of the subject had helped them to learn.

Findings from each of these methods are reported below.

Portfolios

The analysis of portfolios provided a way of getting to know and learn from students, as well as evidence about the evolutionary process of their learning through the semester. In general, students' portfolios started with notes from lectures and relevant literature with little reflection. Later on, students included reflections on their goals, plans, processes for achieving milestones in case studies, performance, strengths and weaknesses, and responses to feedback. Finally they expressed their critical understanding of the sustainability principles in practice, only at later stages of the semester. This indicated that the benefit and necessity of reflective practices were noticed in the last quarter of the semester. While we will make changes to encourage more reflection earlier, we expect that we will continue to see a pattern of development through the semester.

Case Study Reports

The evaluation of case study reports indicated enhanced students learning when compared with case study reports done by students in other, less student-focused, subjects. The qualitative standards appear to have guided students learning and skill development. However, students had difficulties in quantifying social and environmental aspects, and in making a definite and justifiable decision in the design of a sustainable energy system. This is an aspect of the subject, which we will continue to modify with the aim of achieving better learning outcomes.

Student Feedback Survey

In conjunction with *the Centre for Learning and Teaching (CLT),* we designed a set of questionnaires to monitor students' perceptions of aspects of the subject designed to encourage their learning. The analysis of those responses is shown in Table III. Responses were largely very positive. We were particularly pleased that 88% of students seemed to see the value of the reflective exercises, 94% valued the case study, 87% felt they had been able to pursue areas of interest and fewer than 10% disagreed with the value of class discussions and group activities.

Student Interview

Students in Energy Conversion were interviewed at the beginning and the end of the course in order to evaluate the quality of their learning and skill development, and also their reactions to the group work and assessment procedures. They were asked to describe what they learned, and what aspects of the subject enhanced their learning.

Students' Perceptions Of Learning And Skill Development In The Subject

The result of the interviews showed that students perceived that they had gained and valued both understandings of the subject matter and broader professional and personal attributes. In terms of the subject of sustainable energy conversion systems, students generally perceived that they had gained:

1. Familiarity with the technology of power generation from a variety of renewable, non-renewable, and alternative energy sources including wind, hydro, tidal, solar (PV and thermal) energy, biomass, geothermal, co-generation, combined cycles, advanced clean coal technologies, coal, oil, alcohol, or gas fired power stations, nuclear (fission and fusion), and fuel-cell technologies.
2. Awareness of the significance of global, Australian, and local issues in energy conversion, including privatisation, global warming, and CO_2 emission from different energy conversion systems.
3. Familiarisation with the concept of the global-picture of a sustainable paradigm as a desired value system to promote and shape appropriates action.
4. Understanding the significance of sustainable energy systems and implementing its principles through simultaneous consideration of technology, environment, economy and society factors in their case study projects.

In terms of broader skills and attributes, students perceived that the subject had assisted them to:

1. Gain the capacity to self-select suitable case studies project to demonstrate the quality and the quantity of their learning in the subject.
2. Develop their skills to analyse, synthesise, integrate, create, and reflect on materials and apply them in their case studies.
3. Develop skills in team working, and structured and constructive discussion.
4. Improve their self-discipline and the ability to self-organize.
5. Experience and appreciate different value-and-assessment systems through real-life simulation.
6. Develop their capacity to be a reflective lifelong learner and practitioner, through encouraging reflection in the reflective journal.
7. Take more responsibility and control for their own learning, using negotiated assessment standards as guides.

Interestingly, several students reported that in doing the subject they had learned things which they could discuss with their family members and the general public, indicating that they had perceived the broader relevance of the subject to society in general. Some also believed that they could make use of what they had learned to give themselves the edge in future job interviews.

Aspects Of The Subject That Helped Students' Learning

Students used a wide variety of learning methods and reported that they developed skills through actively engaging in learning individually, with a peer, with a team, with the whole class, and through consultation with lecturers. Individual activities reported to particularly help learning included:

- Reading and searching widely [surveying literature, Internet, library, web sites, site visits, and private communications and contacts (eg. power station managers, Aboriginal studies staff in the UTS Indigenous Study Unit, etc]. and analysing of their critical readings and reflections for their weekly reports
- Synthesis, integration, and application of their reflections in their case study.
- Weekly reflections of their personal experiences, noted in portfolios from lectures, handouts, external surveys and feedback.
- Critical reflection on the evolution of their proposed learning contract for the case study.
- Preparation of their weekly oral and written progress reports.
- Self-assessing against learning criteria.
- The need to compare and justify alternative solutions for energy problems.

Peer or team activities most often reported as helpful were:

- Learning from each other in-group discussions during the weekly presentation of progress reports.
- Consultation with their classmates and lecturer (in class, through email, phone, web site, and Topclass.
- Feed back from their own reflections, their peers, their team, their lecturer during interviews and during their weekly oral presentation, and progress reports.
- Critically reflecting on, observing, listening to, questioning, and assessing peers' case study projects.
- Transparent online peer review and discussion processes which enabled students to read each other's work and gain feedback.

CONCLUSIONS

Developing the subject to emphasise sustainability and use student-focused approach to teaching and learning was a challenge which proved well worthwhile. Our own reflections on the experience of teaching the subject and analysis of both portfolios and case studies, together with student interviews, and questionnaire results gave us a clear picture of the effectiveness of the subject. Our overall conclusions were:

- Students had developed their understanding of the complexity of sustainability and their valuing of sustainability as an important aspect of Engineering.
- Students' assessment results showed that they had achieved the overall learning objectives for the subject, including those related to the specific content and professional and personal attributes.
- Students clearly enjoyed and learned from the challenges faced in the subject.
- Students agreed that the student-focused-approach enhanced their learning and skill development.
- We and they perceived that they learned effectively through developing their reflective portfolio.
- They enjoyed the flexibility of choosing a case study in the area of their interest.
- They appreciated being treated as adult learners and being consulted throughout the subject design and evaluation.
- The quality and quantity of learning improved over similar but more strongly content-oriented subjects.
- Students commented positively on their experience of team working and team learning,
- Colleagues in the Faculty were approached by students who requested similar approaches in their subjects.

As the above points indicate, there were many benefits for students in the way that the subject was designed and implemented. Alignment of the learning objectives, teaching and

learning activities and assessment meant that students perceived understandings of sustainability and the development of graduate attributes to be valued and they responded accordingly. This differed considerably from the experience in many Engineering subjects where assessment focuses students' learning on narrow technical content and tacitly encourages them to ignore or devalue broader learning objectives. Student portfolios described how developing their skills in reflective critical learning changed their understanding of concepts and their conceptions of learning. These indicators showed positively that the subject had achieved many of its goals. Difficulties experienced by students related to their relative lack of familiarity with the reflective and team-based components of the subject. By the end of the subject they strongly valued the learning which came from team activities, but on the other hand, it was clear that some students found their early experiences in the teams unsettling. As a result, we now recognize a need to spend more time on developing student confidence and expertise in teamwork, both in prerequisite subjects and in the future offering of the subject.

For the subject lecturers, there were also benefits and disadvantages. The major benefit was the satisfaction gained from improving students learning and seeing them developing the professional and personal attributes required of good Engineers. The main disadvantage was that the initial development and implementation of student-focused approaches in the subject was very time intensive. Effective student learning outcomes were achieved but involved considerable consultation, attention, and prompt response and feed back, especially online through *TopClass* outside of class hours. However, we believe that much of this time related to issues arising during the first offering of the subject, such as team anxiety, which can be addressed in future offerings of the subject. Any new approach to teaching requires a commitment of learning time by teachers, and we are confident that this additional time commitment will reduce as we gain more experience in student-focused approaches learning and teaching.

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BIOGRAPHIES

Jafar Madadnia is senior lecturer in the Faculty of Engineering, UTS. He graduated MSc from the University of London (Imperial College) in 1978, and with a PhD from the University of Liverpool in 1989. He joined UTS in 1994, after five years of post-doctoral research, in the UK. He has developed, lectured, and coordinated both face-to-face and online subjects. He employs student-focused-approaches to enhance student learning. Since 1999, his research focus has been on improving student online education using the *Blackboard* software, and other information and communication technologies.

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EXPANDING THEIR HORIZONS: TEACHING ENGINEERING STUDENTS GERMAN LANGUAGE AND CULTURE

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The School of Electrical Engineering at Curtin University has introduced a liberal elective unit into its first year undergraduate program. Students choose a unit outside the Engineering and Science Division with the aim of broadening their social perspective and improving their communication skills. One of the units available is *German Technology and Society*, which was developed specifically for engineering students with no previous background in language studies. Teaching the unit, especially the language component, has been a challenging task. The initial experience has led to an innovative program, which combines a number of teaching/learning methods, including an on-line component. The paper describes our experiences in developing the program and presenting the unit over the last four years.

CREATING AN ELECTIVE UNIT FOR FIRST YEAR STUDENTS

Engineering courses in Australia have been criticised for emphasising technology at the expense of broader social issues. This leads to the common perception that engineering graduates have a narrow technical focus [1]. A recent report on engineering education by the Institute of Engineers Australia (IEAust) [2] spoke of the need for a cultural change in engineering education, *Future engineering graduates need to be not only technically skilled but also to have a broader appreciation of the context in which engineering is practiced in the 21st century*. Australia, although geographically remote, is part of the global economy and our industries are linked with global markets. The implication is that engineering graduates need to be aware of and sensitive to the global environment in which they will be working.

The under-graduate degree courses offered by the School of Electrical and Computer Engineering at Curtin University address this issue by offering a number of units outside the traditional field of electrical engineering [3]. A particular example is the first year, second

semester elective unit where students choose a unit from outside the field of engineering. Although there is a wide range of units available from other Schools, we felt it desirable to offer a unit which would expose students to the language and culture of another country. A country of some relevance to students in our School is Germany. Following the devastation of WWII Germany has emerged as one of the leading industrialised countries in the world and is at the forefront of many developments in the electrical engineering field. Several German companies are also prominent in Australia (Siemens, Enercon, etc) and are potential employers of our graduates.

A further reason why Germany is of particular interest to our students is the links our School has with two German universities (Aachen and Karlsruhe). Students from both countries have the opportunity to spend a semester abroad, completing a project which is an important element of their normal under-graduate course. Students from Curtin who have participated in this program have benefited greatly from the experience of doing project work overseas in a *real* engineering environment [4].

The challenge was how to develop and teach an introductory German course for engineering students with no previous background in German. As there is no German department at Curtin we enlisted the support of the School of European Languages at the University of Western Australia who were enthusiastic about the prospect. Co-operation between tertiary institutions, staff exchanges etc is another key recommendation made by the IEAust, but one which takes place all too rarely.

Course Structure and Objectives

The unit is organised as two sessions of two hours per week over 14 weeks. One session covers a wide variety of historical (post WWII) and socio-political topics and is presented as a series of lectures, see Table 1. These lectures provide students with an understanding of the socio-political transformation of Germany since 1945, and the role played by technology, industry and government in this process [5]. A feature of this section of the unit is the series of presentations from guest lecturers, including German company directors, the German consul, visiting academics and others with strong German connections.

Table 1. Weekly Lecture Plan

Week	Topic
	Background
1	Germany's birth in the 19th century
2	German society and technology under Hitler
3	Germany's history, society and industry since 1945
4	Germany's industry and society since 1989
5	Germany and the European Union
	Case Studies
6	Germany's education system
7	The EXPO2000 in Hannover
8	Week free
9	WAGBA (talk by local representative)
10	German-Australian connections (talk by German Consul)

11	Working in Germany (talk by exchange students)
12	Future perspectives
13	Final exam

The German language component includes an introduction to the German language, both oral/aural and written, as well as German business culture. The course is at an introductory level, which gives students an insight into everyday German as well as the language of business and commerce. On completion of the unit, students will have learned how to survive (and progress) in a German language environment.

INITIAL EXPERIENCES WITH THE UNIT

The difficulties in presenting the language section of the course (ie a language course for beginners) became apparent after it was presented for the first time in a traditional manner. Compared to a traditional language class one has to consider the following differences:

(i) The amount of class contact time available for a language class is limited. Two hours contact per week is simply not sufficient to achieve the desired learning outcomes. Every week the lecturer had to spend time revising the content from the previous session, which seemed to have slipped into a remote region of the students' brain (despite homework). We found that students tended to do the homework soon after their weekly class when the material was still fresh in their minds and so forgot most of it over the ensuing week.

(ii) The constitution of the class was quite different from a regular language group. Engineering students traditionally have difficulties with English and have strong numeracy, rather than literacy, skills. A further complication is the fact that many students within the School come from Asian backgrounds and English is not their mother tongue.

(iii) The unit is an elective in a course, which most students (especially first years) find very demanding. There is not the same commitment to an elective as there is to a core unit in the course. On the other hand, students elect to take the unit, so usually they are keen to do well and can see the advantages in learning something about Germany and the German language.

CREATING AN ON-LINE COMPONENT

Traditional approaches to language learning work well in an environment where students can focus on the target language, work in small groups and devote an appropriate amount of time to the learning process. In this case, as can be seen from the previous section, we had a group with no background language skills, severe time limitations and studying in an environment where the only foreign language encountered was C++ (a computer programming language).

It was decided that a solution to the difficulties listed was to create extra learning opportunities outside the classroom through a series of on-line learning modules. By making the modules inter-active we sought to actively engage students in the new language as well as tap into their liking for modern, computer based technology. Access to the on-line modules was to be either from a computer laboratory on campus or via the Web at home, adding flexibility to the learning program.

The Multi-Media Centre in the University of WA has developed a package for multi-media authoring, *Storytime,* which is easy to use and allows the user to create modules which combine text, audio, video and images. A decision was made to create a series of small distinct modules targeted at particular language concepts within the course. Three modules were created, Table 2, each having a different structure, which suited the particular concept being taught. In addition, an assessment component was built into each module.

Table 2. Modules

Module name	Language work	Cultural material
Guten tag!	Greetings, introductions, numbers, forms of address	Formal/informal modes A German company: VW
Wieviel Uhr ist es...?	Time, tenses, travel	Problems with racism in Germany
Wie komme ich...?	Directions, tenses, passive	Introduction to a German town (Tuebingen)

Student Response To The On-line Component

The activities within the three on-line modules, their pedagogical rationale and the student response, as gauged from an end of semester survey, are described below,

(i) Exercises providing immediate feedback (multiple choice, fill in the gap etc)

Rationale: to provide students with the opportunity to practice material presented in class and to receive immediate feedback on their input. These exercises were used in all three modules in the context of video comprehension and vocabulary practice.

Student response: students reacted very positively to receiving immediate feedback on their input. Several students said this was the best aspect of the program.

(ii) Video clips

Rationale: to give students greater exposure to spoken German. The students have only two hours class contact per week (and it is in one block), which is simply inadequate for students at this level, especially given the other constraints on their language learning skills. Previous experience with placing audio cassettes in the university library showed most students did not make use of this resource.

Student response: this was again very positive. Typical comments from students on the video segments showed the merit of hearing the language spoken in context,

I liked listening to people speak German and seeing images of Germany.

The video was helpful as the body language aided my understanding of German.

(iii) Interactive map

Rationale: to encourage students to practice asking for and following directions. Using an interactive map with hotspots, students can practice asking for and following directions in a *choose your own adventure* format. In the program they must find their way to four different destinations, but the program is constructed so that there are a number of paths they can take with various activities en-route. If they do not arrive at the desired destination they receive new directions, this means the program is pedagogically better than traditional tapes and text book exercises since:

- it is interactive

- it recreates an authentic situation by giving students the opportunity to ask for new directions
- it involves a significant listening comprehension component not offered by texts
- it introduces the students to a *real* German town through links to pictures of sights they see and the streets along the way

Student response: The *choose your own adventure* format of the mapping exercise was popular. Students enjoyed the chance *explore the town* independently. All students found their way to the intended destinations and demonstrated a marked improvement in being able to ask for and interpret directions.

(iv) On-line homework

Rationale: students complete weekly assignments in the form of worksheets. It was thought that on-line homework, which was directly related to the activities, would appeal more to students. If the homework is enjoyable students invest more time and the learning outcomes improve. At the end of each pathway in the programs there is a link to a homework section which tests the material which has just been practiced. Students enter their answers in an on-line notebook which is automatically emailed to the tutor. The work is corrected and emailed back to the student.

Student response: students appreciated the fast response, this demonstrated clearly how they were progressing with the modules.

Formative Evaluation Of The On-line Modules

Although the on-line components were well received by students there were several criticisms.

(i) students found the on-line component depended on their class work and they found it tedious to look back at class notes during an on-line session. This led to the inclusion of *refresher course windows* which allowed students to revise structures on-line before applying them.

(ii) The programs were developed in a laboratory environment and were designed to run in a university computer laboratory. When converted for the Web it was found that the video segments took a significant amount of time to down-load and students became impatient with the delay. This problem was exacerbated when students ran the programs via modems from home. The delays were reduced by shortening the video segments and changing the video format.

CONCLUSION

According to the unit co-ordinator, who has overseen the course modifications, there has been a marked improvement in the linguistic ability of the students since the on-line component was introduced in 1998. This improvement can be attributed both to the inclusion of the on-line component and experience gained in presenting the course material to engineering students.

Student surveys indicated that students were pleased with the on-line component of the course and most said they would be happy to use it even if it was an optional part of the course. Merits of the on-line modules can be summarised as:

· Interactive multi-media programs are enjoyable for students, hence they are more prepared to *invest themselves* in the course.

· Students are exposed to the spoken language in context, this leads to improved pronunciation and comprehension skills.

· The on-line assessment feature of the program facilitates learning since it avoids the long delay between completing an exercise, having it marked and receiving feedback.

Enrolment in the German unit has fluctuated from 15 to 35 over the four years the unit has been offered. The School of Electrical and Computer Engineering now has in place an active program for student exchanges between Germany and Australia and returning students spend a semester in the School before graduating. It will be interesting to see how popular the German elective unit becomes and whether there is a connection between students taking the unit in semester 2 and spending a subsequent semester in Germany.

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