Australian Council of Engineering Deans

Engineers for the Future

addressing the supply and quality of Australian engineering graduates for the 21st century

Robin King

This report is an outcome of a project undertaken by the Australian Council of Engineering Deans with support from the Australian Learning and Teaching Council, Engineers Australia, the Australasian Association for Engineering Education, and the Australian Academy of Technological Sciences and Engineering.

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This report is an outcome of an original project undertaken by the Australian Council of Engineering Deans (ACED) and supporting partners, under the title *Addressing the Supply and Quality of Engineers for the New Century*. The key findings are also published separately under the title, *Engineers for the Future: addressing the supply and quality of Australian engineering graduates for the 21st century – summary and recommendations.*

Support for this project has been provided by the Australian Learning and Teaching Council, an initiative of the Australian Government Department of Education, Employment and Workplace Relations. The views expressed in this report do not necessarily reflect the views of the Australian Learning and Teaching Council Ltd.

The original project report may be accessed at http://www.altc.edu.au/carrick/go/home/grants/pid/343

The project was administered by the University of Technology Sydney, with key personnel:

Project Leader:	Professor Archie Johnston, ACED Past President Dean of Engineering, University of Technology Sydney
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Project Assistance:	Emeritus Professor Alan Bradley, Engineers Australia
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Foreword

Over the last two decades at least, Australia's engineering education system, through its engineering schools, professional institutions and related academies and societies, has demonstrated an ability to reflect on its practice and performance and adapt to changes of technology and the changing expectations of society. Indeed, these stakeholders have endeavoured to anticipate future needs, and position the system to develop graduates who are well equipped to take leading positions in the profession and society at large.

The current project has built on the mid-1990s review of engineering education, published as *Changing the Culture: engineering education into the future.* The recommendations of that review led to comprehensive revision of the program accreditation processes and substantial curriculum innovation and reform. Despite these good outcomes, the anticipated increase in participation by women reached only a relatively low plateau around 2001. The demand for Australian engineers continues to exceed graduate supply. Engineering study has remained a distinct minority interest for most Australian school leavers. Increasing the size of the pool of qualified and motivated school leavers for engineering study present continuing challenges.

This report is the outcome of the consultative review of the national engineering education system undertaken during 2007 by the Australian Council of Engineering Deans with strong support from Engineers Australia, the Australasian Association for Engineering Education and the Academy of Technological Sciences and Engineering, and funding from the (then) Carrick Institute for Learning and Teaching in Higher Education Ltd. The research methodology and implementation were largely devised and carried out by Emeritus Professor Robin King, who also authored the report.

The study examined the state of the engineering education system, with respect to its ability to meet future challenges. The study revealed a diverse and responsive system, many examples of good practice in engineering education that provide a sound platform for future development, and many highly able, articulate and ambitious students and graduates. The study also found system stresses: increasing student-staff ratios; difficulties in making academic appointments at all levels; lower incentives within the system for improving teaching than for developing research; inadequacies in the provision of laboratories; and variable connectivity with industry. The study found a stakeholder community believing strongly that a good engineering degree can be a passport to success in many of life's endeavours, seeking to ensure that its degrees are indeed 'good', and that they deserve to attract to a wider sector of the population. As part of the project, ACED developed a vision for the engineering education system.

The Steering Committee guided the review towards recommendations for future action that will ensure Australia continues to operate an engineering education system capable of meeting Australia's current and future needs and maintain parity with international best practice. Already, five months after completion of the study, actions are in place for several of the recommendations. In commending the report and its recommendations, I record my thanks to my colleagues on the Steering Committee and all who contributed to the review especially Robin King whose dedication to engineering education and wisdom in steering us to a new vision for engineering in Australia shine through this report.

Mary O'Kane
Chair, Steering Committee
October 2008

Executive Summary

Engineers conceptualise, create and maintain physical and information-based products, processes, systems and assets that satisfy human and economic needs, and have minimal environmental and negative human impacts. Engineering is critical to Australia's economy, security, health and environment, is increasingly complex and multidisciplinary, and is practised diversely, in business, government and educational enterprises. Engineering is a key component of the nation's innovation system.

Australia's higher education sector provides entry-level education to professional engineers, engineering technologists and engineering officers, as well as advanced level education and engineering research. The engineering education system, involving educators, professional bodies and employers, enjoys good international standing. The system is operated by the engineering schools (this term is used to identify each university's operational entity responsible for providing engineering education, irrespective of the university's academic structure and nomenclature) in 32 of Australia's universities, with a highly diverse range of award programs in metropolitan and regional cities, and overseas. The system has responded continuously to changes in engineering practice brought about by new scientific and technological knowledge, and to changing economic and regulatory forces.

This report is the result of a year-long study of the state of the higher education component of the Australian engineering education system, with respect to its ability to address future needs. The study involved submissions and consultations with about 1000 engineering academics, engineering professional, students and graduates. Most of the data presented has been sourced from the Higher Education Statistics collections of the Department of Education, Employment and Workplace Relations (DEEWR).

The study also assesses the implementation of outcomes of the 1996 Review of Engineering, *Changing the Culture*. That review recommended changes to the engineering program accreditation process as well as to the curriculum. Accreditation changes introduced from 1999 are judged to have been successful in driving greater emphasis on generic graduate attributes in first-degree engineering programs. The present study has identified that the previous review provided the stimulus to many improvements in curriculum design and delivery, including greater adoption of project, problem, and workplace-based learning, and increased emphasis on sustainability and management. The anticipated growth of engineering student numbers and increased participation by women did not eventuate, however, and Australia's demand for engineers continues to exceed graduate supply. There have been, however, indications of increasing demand for engineering programs from 2007.

The present study has identified substantial and emerging strengths of many of Australia's engineering schools in the areas of research, international education, and in addressing industry-specific skills shortages though both undergraduate and postgraduate programs. The report provides examples of best-practice in some of these areas, as well as in curriculum innovation and outreach to schools. The study found many excellent and well motivated students in the system. The report also outlines some of the emerging issues in national and international engineering education.

The study also reports on the stakeholders' concerns about the educational capacity and robustness of the engineering education system with respect to its ability to graduate increased numbers of engineers with the qualities that are required for the future. The principal issues include:

- the continuing reduction in the size of the pool of Australian school students who are studying the requisite high levels of mathematics and science, and are thus qualified to enter engineering programs;
- the continuing low participation of women, and other minority groups in university engineering programs;
- high levels of student attrition from engineering programs;
- low levels of enrolment in engineering technology programs, and variable appreciation of the merits of such qualifications amongst industry and employers;
- low levels of enrolment in coursework technical masters programs by Australian engineering graduates;
- declining commencing enrolments by Australian engineering graduates in higher degrees by research;
- decreasing financial resources for teaching in the engineering schools, with corresponding worsening student-staff ratios;
- difficulties in appointment and retention of well-qualified engineering academic appointments, with apparently lower incentives within the system for improving teaching than for developing research;
- inadequacies in the provision, equipment and support of many of the laboratories in engineering schools;
- highly variable connections between the engineering schools and industry, resulting in uneven exposure of engineering students to contemporary practice;
- concerns that the balance of subjects within current engineering curricula are not adequately matched to graduates' and industry's current and future needs; *and*
- widely-held concerns that the societal value of engineering as a profession, and the broad merit of engineering a study pathway that increases graduates' career opportunities, are largely invisible to the public at large and within the school education sectors.

The six recommendations address these issues to ensure that the engineering schools can meet the country's future needs for engineers. Each of the recommendations has an identified leader, stakeholders, and performance measures and indicators, and is elaborated into a set of specific actions. The leading stakeholders, ACED and Engineers Australia have formally committed to work on these recommendations collaboratively and with the supporting stakeholders. The report concludes with a short summary of new projects funded by the Australian Learning and Teaching Council being undertaken by ACED and AAEE members that specifically address one or more of the recommendations and actions.

Recommendations

Recommendation 1: raise the public perception of engineering

Raise the public perception of engineering, including within primary and secondary schools, by increasing the visibility of the innovative and creative nature of engineering and the range of engineering occupations that contribute to Australia's prosperity, security, health and environment.

Recommendation 2: refine the definition statements for engineering occupations and graduate qualification standards

Develop, support and promote the concept, reality and importance of all members of the engineering team – Professional Engineers, Engineers Technologists and Engineering Officers – in the successful implementation of engineering work. Review the graduate competencies and reference standards for the qualifications for each level.

Recommendation 3: implement best-practice engineering education

Engineering schools must develop best-practice engineering education, promote student learning and deliver intended graduate outcomes. Curriculum will be based on sound pedagogy, embrace concepts of inclusivity and be adaptable to new technologies and inter-disciplinary areas.

Recommendation 4: improve resources for engineering education

Enhance staff and material resources to enable delivery of engineering education that is demonstrably aligned with Australia's needs and compliant with international standards.

Recommendation 5: engage with industry

Engineering educators and industry practitioners must engage more intensively to strengthen the authenticity of engineering students' education.

Recommendation 6: address shortages by increasing diversity in engineering workplaces supported by engineering education programs

Address shortages in the engineering workforce by attracting and retraining people from non-traditional backgrounds e.g. women, mature age engineers, engineers with overseas qualifications, engineers who have left the profession, and engineers wishing to articulate between qualification levels. Ensure the future needs of employers are matched by the number and types of programs on offer.

A Vision for Australian Engineering Education

The Australian Engineering Education system provides diverse, high quality, internationally respected, industry focussed, professionally accredited education programs. These are delivered in well resourced, internationally benchmarked facilities by internationally regarded specialists in engineering and engineering education. The engineering programs have a strong emphasis on engineering practice, engineering design, creative problem solving and innovation. The system aims to support society at large towards enhancing the quality of life and securing a better future for all.

The education programs offer a wide range of pathways and choices to attract school leavers and mature entrants from diverse backgrounds. They inspire and prepare students to become creative, inventive and responsible professionals as well as life-long learners. Graduates will make positive contributions to their profession. Many will work towards solving significant challenges, such as global sustainability, water and energy supply. The education system provides a platform for launching graduates into influential leadership roles in engineering and other fields.

Australian engineering education is responsive and adaptive to technological, professional and societal needs. Operated across a wide range of universities and other educational institutions, the system strongly encourages collaboration between educational providers to maintain the highest possible standards and efficacy of delivery. Engineering academics and their work are highly regarded by students, graduates, employers, the engineering profession, and within their institutions.

The Australian Engineering Education system is recognised internationally as a global leader in engineering education through its well-researched and focussed contributions to educational developments and to the development of international accreditation standards. The system undertakes periodic review processes to evaluate its performance and recalibrate its objectives.

ACED April 2008

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1. Introduction

1.1 Background and aims

The current project has its origins in the desire of the stakeholders of the 1996 national review of engineering education (Engineers Australia, the Australian Council of Engineering Deans, and the Academy of Technological Sciences and Engineering) to evaluate the impact of that review[1] (referred to here by its short title *Changing the Culture*) as a driver of change in the engineering education system.

The desire for a review project was enhanced during 2005-6 by increasing and widespread concern that the current high demand for engineering graduates is not being met by corresponding increases in student demand for engineering education programs. Engineering skills shortages pose significant and complex challenges, and therefore responses need to be supported by valid information and sound industry and academic insights. Broad stakeholder engagement in any review is essential to ensure both accuracy of findings, and to provide well grounded support for its recommendations.

The Carrick Institute for Learning and Teaching in Higher Education was formed in 2004 to be a national focus for the enhancement of learning and teaching in higher education. The institute's discipline-based initiative (DBI) program has provided competitive funding for 'scoping' the issues of concern in discipline-based education. Studies funded under this initiative are required to develop a vision, action-oriented recommendations, and a dissemination strategy for the study results. This specific report is part of the latter, and contains the material in the project report[2] submitted to the funding body, renamed the Australian Learning and Teaching Council in May 2008.

In its process of developing the proposal for the present project in late 2006, ACED identified eleven issues. In summary, these encompass: evaluation of impact of the 1996 national review; impacts of the declining high school preparation in the enabling sciences and mathematics; international and mobility issues; gender balance; graduate outcomes; the value of engineering education as an enabler to different career options; industry-university partnerships; resources; student attitudes and culture; and engineering and education research linkages. Most of these issues were addressed in the scoping study and this report.

The ultimate agreed aim of the project was: '*To ensure that the engineering education sector across Australia's universities produces in a sustainable manner, a diverse supply of graduates with the appropriate attributes for professional practice and international relevance in the rapidly changing, competitive context of engineering in the 21st Century*'. Appendix 1 provides a summary of the agreed project proposal.

The project aim reflects directly the prime responsibility of Australia's engineering education system to provide education programs at associate degree, bachelor and postgraduate degree levels for Australia's engineering workforce. (Universities share responsibility with the VET sector for associate degrees.) The high levels of responsibility carried by engineers of all levels and the global nature of engineering practice necessitate that Australian engineering education be conducted to the highest international standards.

These needs require that Australian engineering education be operated as a ***system*** involving higher education, employers, and the national and international professional accrediting bodies. The objective of this system is to add value to each student's capability and potential through the education programs operated by the engineering schools. An individual student may pass through several engineering programs in a process of life-long learning: a bachelors graduate may later become a postgraduate student at another institution, for example. The engineering schools seek to maximize their impact through the valued attainments of their graduates, and by taking advice from employers and professional bodies. All the stakeholder groups (Appendix 2) in this model of the engineering education system are committed to continuous improvement of engineering education through periodic reviews.

1.2 Investigation strategy and information sources

The project proposal and the proposed investigation strategy were discussed and endorsed at the ACED meetings in December 2006 and March 2007 respectively. The Project Manager was appointed to work approximately half-time for 12 months. The details of the consultative methodology, as described below, were developed by the Project Manager in discussion with the project Steering Committee (Appendix 3) to ensure broad stakeholder engagement (academic, industry and the professional body, students and recent graduates) with the project and its outcomes.

The consultative methodology ensured that:

- the commentary and evaluation of the recommendations of the 1996 *Changing the Culture* report would include input from many involved with implementing the outcomes of that review (see Chapter 3);
- critical issues, together with explorations of future directions for engineering education, would be identified in ways that would readily lead to action priorities in areas in which students and academics, industry and the profession have largely shared views.

Draft recommendations were developed jointly by the Project Manager in consultation with members of the Steering Committee during November 2007. ACED considered them in detail, together with a draft of relevant sections of the draft report, at its meeting in December. The council members engaged in group activities to propose improvements and action priorities, and endorsed the draft recommendations and draft report. The report to the funding body was completed by the author, in consultation with the Steering Committee.

The following paragraphs describe the key sources of information used in the study.

<u>Deans' Issues and Innovations</u>

At the commencement of the project the engineering deans were requested to provide lists of critical issues and of successful, evaluated, innovations in engineering education. The issues identified were explored further in the facilitated consultation processes and provide the content of much of this report. The innovations, several of which are reported in Chapters 4 – 10, are a selection of good examples of educational improvements and responses to changing needs. Many other equally noteworthy examples could have been provided.

<u>Focus group consultations</u>

These focus groups consultations used question sets (see Appendix 4) that were approved by the Steering Committee and adapted to the interests of each group. The consultations were held in 14 cities with designated groups in universities (schedule, Appendix 5, part A). Deans made local arrangements to facilitate direct access to academic staff, students and early year graduates, and where possible, industry advisers. Facilitated mostly by the

Project Manager, some of the consultations involved other Steering Committee members. Most of the university visits were completed within the first half of the project, enabling subsequent consultations to concentrate on elucidating the major emerging issues and prospective actions.

Engineers Australia assisted the Project Manager to arrange consultations with its city-based Division committees, and its disciplinary-based College boards and working committees (Appendix 5, part B). Several of these boards also provided relevant papers from their ongoing work, and written submissions. Engineers Australia also organised an industry-university workshop at the annual AaeE Conference in Melbourne to provide input into the project.

Contributions from individuals

Engineers Australia published requests for submissions in its monthly magazine and e-News and also arranged a web-site for receipt of submissions. During the second half of the project, the Project Manager contacted a small number of influential individuals (Appendix 5, part C) to comment on specific emerging issues. The list of submissions is provided in Appendix 6.

Further information sources

The study has drawn on many published sources. Higher education statistics were sourced from the Commonwealth Department of Education, Employment and Workplace Relations (DEEWR), either directly or via Engineers Australia's biannual statistical compilation[3]. The 2008 edition of the latter will contain much of the student enrolment and graduation data presented here in graphical form. The datasets provided by DEEWR are largely compiled from submissions by the individual universities. The author of this report is responsible for the compilation and interpretation of data as presented here.

1.3 Report outline

The report sets the context of Australia's engineering education system in Chapters 2 and 3. Chapter 2 identifies current and emerging issues for engineering occupations and qualifications. Chapter 3 provides a summary of the outcomes of the *Changing the Culture* review, addressing each of the fourteen recommendations. This chapter contains a detailed commentary on the development and implementation of the outcomes-based accreditation process.

Chapter 4 provides a profile of the engineering schools, including aggregated student and staffing data for the decade since the earlier review. This chapter also comments on the wide diversity of engineering education provision, and the growth of international activities and research. Chapter 5 summarises the study findings on employer demand, illustrated by data from quantitative studies of engineering skills shortages in the mining sector and the Hunter region.

Chapter 6 turns to the student side of the demand question and explores two specific factors that limit the size of the pool of qualified and motivated students: participation in secondary school mathematics and the low attractiveness of engineering to women. This chapter concludes with a discussion of how pathways for engineering could be increased.

Chapter 7 provides a summary of recent engineering curriculum developments in Australia, illustrated with examples of good practice selected from material submitted by deans or revealed in the focus group discussions. The chapter includes comments on emerging generic attributes for future engineers and emerging curriculum design and implementation issues. Chapter 8 examines the issue of resources, in terms of staffing and laboratories, and provides examples of sharing expertise and other resources between engineering schools.

Chapters 9 and 10 provide perspectives on linkages between engineering schools and the school education sector, the public at large, and industry. Both chapters include illustrative examples of good practice.

The recommendations are provided in full in Chapter 11.   Each of the recommendations has an identified leader, stakeholders, and performance measures and indicators, and is elaborated into a set of specific actions. The report concludes with a Postscript that summarises the public exposure of the findings of the project report (a list of conference presentations is provided in Appendix 6), and the status of continuing funded work on the recommendations.

2 Engineering occupations and the engineering education system

Engineers have society's trust in conceptualizing, designing, implementing, producing, operating, maintaining, and ultimately disposing of physical and information assets, in the forms of infrastructure, systems, products and services. Engineers are thus concerned essentially with creating new futures and solving practical problems, safely and responsibly. Engineering is a key ingredient of innovation. Many commentators situate ***design*** as the defining theme and activity of professional engineering, a topic discussed further in Chapter 7. Historical analyses of the profession, such as that by Auyang[4], describe how the occupations and activities of practising engineers have continually changed and adapted to new scientific and technological knowledge, and to changing economic and regulatory forces. Engineering education can only retain its relevance by continuing to respond to these and other forces within society, and often by taking a lead on emerging issues.

2.1 Engineering occupations and qualifications

Engineering enterprises employ personnel formally qualified to practice engineering at several levels, including the three occupational categories designated by Engineers Australia, viz. professional engineers, engineering technologists and engineering officers (also known as associates or technicians), together with technical staff and tradespersons educated at certificate levels. Engineering work in large organisations is most often carried out by teams including staff qualified at all levels. Small engineering organisations may, in contrast, employ engineering staff from only one or two categories. In practice, there is considerable overlap in the actual work and responsibilities of personnel at the various occupational levels. Engineering personnel of all levels are also employed in government, health, education and other sectors of the economy.

In Australia, the higher education (university) sector currently has sole responsibility for education to the first two levels, through 4-year (or equivalent) post-secondary school professional engineering awards such as the Bachelor of Engineering (B.Eng.), and 3-year engineering technology awards such as the Bachelor of Technology (B.Tech.) respectively. The higher education sector shares responsibility with the vocational education and training sector (VET) for providing award programs for engineering officers, through 2-year Associate Degrees and Advanced Diplomas in the university and VET sectors, respectively.

These education qualifications are assessed by Engineers Australia for accreditation against the Stage 1 National Generic Competency Standards which define the level of preparation necessary and adequate for entry to practice at the appropriate occupational level. Stage 1 competencies provide the starting point for entry to the profession and after a period of professional formation, graduates may submit for competency assessment at the Stage 2 level, as the formal pathway to Chartered status within Engineers Australia and/or national registration. Chartered status is conferred at each respective occupational level once specific workplace competencies are demonstrated.

Engineers Australia is active within the International Engineering Alliance (IEA)[5] that incorporates the Washington, Sydney and Dublin educational accords as well as multilateral mobility agreements for practising engineers and engineering technologists. The Washington Accord, Sydney Accord and Dublin Accord apply to the professional engineer, engineering technologist and engineering officer occupational levels respectively. The Accords formally recognise the substantial equivalence of the outcomes of the accreditation processes practised by individual signatories and thus recognise the accredited education programs listed by each signatory to the Accord. The IEA has published a graduate profile exemplar guide to the attributes and competencies of graduates at each of the three occupational levels (Appendix 7). In summary, the distinctions between the occupational levels are made around competence of the professional engineering graduate to work with ***complex*** engineering problems, the technologist graduate with ***broadly-defined*** engineering problems, and the technician graduate to work on ***well-defined*** engineering problems. These distinctions are important for defining skills shortages, and considering educational strategies to address them. The detailed statements are currently under review by the IEA in order to ensure their currency while addressing international developments and needs.

Table 1 Mappings between engineering qualifications and the Australian Qualifications Framework. The 'years' column shows the minimum post-secondary school certificate full-time university study time in engineering at most Australian universities.

AQF: vocational education & training sector accreditation	AQF: higher education sector accreditation	Engineering occupations: entry level qualification accreditation	years post senior sec school certificate
	Doctoral Degree		7.5
	Masters Degree	may be equivalent to a 4 year engineering degree (see text)	5
Vocational Graduate Diploma	Graduate Diploma		4
Vocational Graduate Certificate	Graduate Certificate		3.5
	Bachelors Degree (includes all 3 and 4 year, dual degrees and honours)	4 year degree for professional engineers 3 year degree for engineering technologists	3 – 4
Advanced Diploma	Associate Degree and Advanced Diploma	engineering officer (formerly engineering associate)	2
Diploma	Diploma	no designation	

Source: adapted from AQF Implementation Handbook (reference 6)

Notes:
1. Trade Certificates (AQF Certificate III) are at two steps below the Diploma level.
2. Many universities have provided 'Diplomas' at the AQF Advanced Diploma level
3. The AQF makes no distinction between postgraduate research and coursework awards

The three qualification levels map onto the Australian Qualifications Framework[6] (AQF) post senior secondary school certificate classifications as shown in Table 1. This mapping is important with respect to articulation between engineering qualification levels. The occupationally-defined engineering qualifications do not map uniquely to the AQF levels. In particular, the B.Eng. and B.Tech. awards lie at the same AQF level, but differ in duration, and are occupationally distinct. Although the university-based Associate Degrees and VET-based Advanced Diplomas lie at the same AQF level (and occupational level), they have different intended learning outcomes and curriculum approaches, as discussed later.

Emerging Issues

The present study has revealed a widespread lack of formal understanding by many employers and practising engineers of the differences and complementarities of these competence, qualification and occupational classifications. Whilst employers report widespread skills shortages in engineering (Chapter 5), this study has found that many employers do not recognise the engineering technologist occupational category as such, but in some cases employ graduates from professional engineering programs under a role description that is more closely aligned with that defined by Engineers Australia for the engineering technologist, rather than that for the professional engineer. In itself, this is not surprising since more than 80% of first-degree graduates from Australian engineering schools qualify with a 4-year Bachelor of Engineering (see section 4.2).

Many universities that have offered 3-year programs at the engineering technologist level have experienced very low demand from school leavers. There are widely held perceptions that 3-year engineering technology programs are in some ways inferior. Some programs define the award as a fallback exit point for students not progressing in their Bachelor of Engineering studies. Many students regard it as (merely) an alternate entry pathway to the Bachelor of Engineering. Some exceptions to this are discussed later.

Many consulted within the study have, nevertheless, questioned whether the current system is ideal, asking whether the apparently 'one-size-fits-all' Bachelor of Engineering system actually serves all students and employers well. As discussed later, there is considerable diversity of provision of the B.Eng. award. It is tackled by student cohorts with a very wide range of educational experience and aptitude. But the relatively high attrition of students from engineering study programs may indicate that the system is operating sub-optimally. A more strongly differentiated set of awards more closely related to occupational needs might better meet skills shortages, ***if operating such a set increases the number of graduates entering engineering occupations as a whole***. The current range of education programs offered within the system is outlined in Chapter 4 and Appendix 8.

One of the reasons for the emphasis that employers place on the professional engineering qualification is the perceived need for graduates to progress to the Stage 2 competencies and to acquire registration on the National Professional Engineers Register. The National Engineering Registration Board was established jointly by Engineers Australia, the Association of Professional Engineers, Scientists and Managers (APESMA), Australia and the Association of Consulting Engineers Australia, and maintains both the National Professional Engineers Register and the National Engineering Technologists Register.

Under state and federal legislation, registration is required for the conduct of defined engineering functions whose outcomes have inherent and potential risks to the public. The design of major structures and provision of engineering services associated with buildings have long been seen to be in this category. Public risk is now seen to have a wider scope than in the past, and as engineering services and systems have become more pervasive, it is legitimate to question whether ***all*** professional engineers should be formally and legally registered to practice, as in the case of many other professions, and is the case for all engineers in Canada. Such a requirement, supported by more employers providing formal graduate development programs, could significantly improve the status of the profession of engineering, an ideal supported by many individuals consulted within this study (see Chapter 9).

The following paragraphs outline some of the issues raised at the educational system level that relate to the future provision of education for each of the occupational levels. It is these issues that underpin the specific proposals in Recommendation 2. In contemplating any major revisions to the engineering education system, all those consulted in the review agree that the system must allow students and graduates to transfer between qualification pathways with maximum efficiency, in terms of allowed credit and study duration. To address the skills shortage, the system must also attract a higher proportion of women, a greater share of top-ability school leavers, and more mature entrants and re-entrants to engineering education.

2.2 Educating tomorrow's professional engineers

Most contemporary statements about the activities of professional engineers stress their roles in solving complex and relatively undefined problems, as well as the innovative and creative elements of the profession. Professional engineers are expected to be the leaders of engineering teams and of the profession, and undertake a diverse range of responsibilities and roles. As noted earlier, their activities and responsibilities may also overlap those of engineering technologists and engineering officers.

Many professional engineers will work at the leading edge of engineering science and practice and will initiate and implement highly innovative engineering ventures. Others will also be expected to apply contemporary engineering methodologies to solve more routine problems in infrastructure renewal or manufacturing and processing. Many consulted in this study also referred to the need for engineers to work alongside professionals from other disciplines (including architects, urban planners, construction managers, computer scientists, environmental scientists, economic geologists, medical practitioners, mathematicians and professional managers), as well as with engineering technologists and engineering officers. All professional engineers are expected to be effective project managers. What professional engineers actually do (as opposed the functional roles they have), and how this should influence what their education qualifications should comprise, is the subject of current research being undertaken by Trevelyan[7] and colleagues at the University of Western Australia.

The study revealed strong support for engineers taking a high profile in issues of sustainability and the impact of climate change. A senior engineer[8] in one major Australian company already appoints graduates as 'sustainability engineers' to reinforce the importance of thinking and designing long-term sustainable engineering solutions. Many engineering students talked of the opportunities for work in renewable energy and water resources engineering. Others were excited by the prospects of working in emerging areas such as bio-materials. Many see professional engineering as a good route to management.

In considering this diversity, the discussions pointed to categorising professional engineering work as being primarily concerned with either:

- advancing and applying advanced engineering science and technology; or
- advanced project management and systems integration.

These categories are similar to those proposed in a recent industry study[9] commissioned by UK Royal Academy of Engineering that referred to future engineers' roles as 'specialists', 'integrators' and 'change agents'. The strong and specific Australian emphasis on the role of engineers in project management and maintenance of major engineering assets was conveyed by many of those consulted in this study. This may be a point of difference in focus from that of the UK study. Irrespective of the particular categorisation, education for professional engineers must reflect the needs of diverse practice.

Most contributors to this study argued that the educational preparation of the next generation of professional engineers needs to be both deeper (in one or more aspect) and contextually broader. (The latter was also a major theme of *Changing the Culture*.) Faced with the apparent pressure of having to fit more into the curriculum, many contributors to the present study stated that the first degree must concentrate on foundation material, leaving more contextual or technically advanced material to postgraduate studies and other avenues of professional development. Curriculum issues are addressed in Chapter 7.

With professional engineering practice increasingly global in scope and operation, and many graduates of Australian universities practising internationally, all stakeholders have signalled the importance of maintaining the current high international standing of Australian engineering schools and engineering education programs. As noted earlier, this is achieved formally by program accreditation by Engineers Australia, and Engineers Australia's signatory status with the Washington Accord[10], as one of educational accords under the IEA that recognises the substantial equivalence of the accredited engineering programs offered in signatory jurisdictions/economies.

Facing similar challenges of graduate supply and quality that underpin this study, several signatories to the Washington Accord have committed to extend the duration of their professional engineering programs or adopt a masters degree as the qualification for enrty to practice, within the next two decades. The UK Engineering Council already requires a Master of Engineering (M.Eng.) qualification, normally awarded after four years of study in England and Wales, and five years in Scotland, reflecting their different school education systems. The Royal Academy of Engineering UK has recently published[11] the findings of further study on the future needs of engineering education, including a comprehensive set of recommendations to raise the standing and student demand for engineering education. Ireland's professional accrediting body, Engineers Ireland, has adopted policy requiring accredited engineering programs to be of five years post-secondary duration for graduates from 2013[12]. This aligns with the European adoption of the two cycle 3 year + 2 year Bologna program model[13] in which qualification for entry to professional engineering is normally after the second cycle, normally a masters degree. The US National Academy of Engineering[14] has proposed that entry to professional engineering will require a masters degree qualification awarded six years after the completion of secondary schooling. The NAE report observes that engineering is the only American profession that does not require a master's level entry qualification. The American Society of Civil Engineers[15] has already adopted a process that moves towards this standard.

Whilst program duration is only one element in the process of ensuring the quality of professional engineering graduates, it is timely to question whether Australia's current pattern of professional engineering education, established around 1980, is sufficient for the initial educational formation of future professional engineers. Many consulted in this study, particularly from industry and the Engineers Australia College boards, asserted that moves towards a five-year award are either desirable or inevitable for a number of reasons. Some protagonists emphasised the need for additional study time (including foundation studies and bridging programs) principally to compensate for the apparent declining levels of mathematics and science presented on commencement of engineering study, and to reach the current defined graduate outcomes. Others stressed arguments around the need for increased depth and breadth in engineering programs required for graduates to enter employment at the professional engineer level. These two drivers are clearly very different.

The fundamental and overriding drivers in considering any future changes to the basic structure and duration of engineering programs must be to ensure that all Australia's accredited professional engineering degree qualifications continue to meet international standards, as they unfold in time. A requirement for professional engineering to move to five years of full-time study would not be groundbreaking in Australia: the profession of architecture now requires a five-year post-secondary higher education qualification, normally a masters degree[16], in accordance with the Australian Qualifications Framework.

2.3 Professional engineering education in Australia: a diversity of program structures

What characterizes professional engineering education in Australia? Many employers commented on the excellence of many B.Eng. programs, often citing the strong focus on design and project work. This is indeed higher than most overseas engineering programs[17]. Secondly, current B.Eng. programs appear to satisfy, at least as well as other first degree programs, the business community's demands for graduates to possess, on graduation, generic qualities such as problem solving, project management, communication and teamwork skills. Not surprisingly, many engineering graduates gain employment in the financial and business sectors. The Australian community also values good industry practice, although the extent to which this is incorporated into degrees is quite variable (see section 6.5).

A further characteristic of the Australian engineering education system is the diversity of programs that meet the qualification requirements to enter a professional engineering career pathway. While the 4-year full-time B.Eng. is the standard route (and is the core format examined in accreditation), in some universities this is taken by a minority of the student cohort. There are four five-year patterns:

a) ***Combined, double or dual degree*** pathways (all subsequently referred to in this report as 'dual') with science have a long history in Australia and most often intensifies graduates' capacity for more technical and research oriented engineering. Dual engineering-arts, engineering–commerce and engineering-management combinations introduced from the early 1990s have proven particularly attractive to women, and provide students and graduates with broader study and career options. Some of Australia's most brilliant students have chosen to take engineering in dual degree formats, and have progressed to high-level careers. The Engineers Australia accreditation process considers only the delivery of the essential engineering outcomes of such combination programs, taking into account double counting of some courses to both degrees. Dual degree combinations with some professional disciplines, such as law, normally require more than five full-time years of study.

b) ***Integrated masters*** programs have a masters component built directly on three or more years of prior study in such a way that the outcomes of the whole program can be explicitly considered in the accreditation process. A good example of this model is the 5-year B.Eng/M.BioMed Eng. engineering program at the University of New South Wales. The new 'Melbourne model' 3+2 year program offered to commencing students at University of Melbourne model from 2008 is a variant on this pattern, with the first component being one of four three-year bachelor awards, none explicitly in engineering. Students wishing to progress to the two-year M.Eng. take appropriate major studies within their bachelor program[18]. In this latter model it is the 3+2 year program sequence that ultimately delivers the accredited, professional engineering outcome.

c) ***Monitored industrial placements*** are included to extend the total educational experience, and may result in the award the B.Eng. and an additional qualification. Examples of the latter include the award of the Diploma of Engineering Practice from the University of Technology Sydney and from Central Queensland University.

d) ***A two cycle engineering model*** operates at the University of Ballarat and the University of Southern Queensland. Students first complete a 3-year Bachelor of Engineering Science or (B.Eng.Sc.) (accredited at the engineering technologist level), with articulation possible to a 2-year masters program. The combined five-year sequence of study has been accredited by Engineers Australia at the professional engineer qualification level.

B.Eng. awards (or their equivalent), being four-year awards, are generally offered as 'honours' degrees to students who satisfy the required academic standards set by each university. Since Australian universities are autonomous, self-accrediting institutions, there are significant variations in the mechanics of honours grade classification[19]. Nevertheless, such classifications are able to identify achievement levels in three or four classes of honours, with the uppermost generally indicating that the holder has an aptitude for postgraduate research, with high grades often achieved in advanced-level coursework and/or a research-oriented project. The award of honours grades in engineering degrees, as such, was not a topic of much debate in the focus group consultations undertaken in this study, but incorporating research in undergraduate engineering projects is discussed further in Chapter 7.

Emerging Issues

Dual degrees appear to have served engineering education well in attracting women and high calibre school leavers to engineering studies. Engineering schools rightly celebrate their success. Nevertheless, some consulted in this study have the opinion that dual degree graduates represent 'a loss to engineering' if they do not practice in the field. Others expressed concern that engineering content is sometimes compromised in order to accommodate a second degree outcome within the limited study time allowed. The proposition that 'engineering is attractive because it can be taken with other degrees', when single award engineering programs are not demonstrating high demand may, in fact, weaken the intrinsic position and status of engineering. The emergence of special engineering programs for top-ability school leavers is discussed further in section 7.3.

The consultation process stimulated considerable discussion around the concept of future programs for professional engineers being based around the Bologna style two-cycle model. In general terms, the Bologna two-cycle process is broadly compatible with Australia's three-year first degree pattern in arts, science, and commerce. The University of Melbourne 3+2 model has this general form, as does the two-cycle engineering degree model, both described above. The discussions raised many ideas and issues, including:

- that the masters component could develop thematic majors in advanced engineering science, systems integration or project management, related to the chosen branch of engineering;
- that the model could normally include (at least) one semester of well-managed industry-based learning (or research institute-based for students on an advanced engineering science track);
- that the established success of dual degrees must not be lost;

- that the qualification outcome of any first cycle award must be meaningful for graduates and employers, and accredited within the Engineers Australia and international accreditation systems;
- that new second cycle masters degrees must be compatible with (or be clearly distinct from) other 'stand-alone' masters awards. At present, Engineers Australia does not accredit 'stand-alone' master's degrees that are offered in a wide range of engineering science specialisations, nor those in engineering practice and management. Such awards generally provide a professional development pathway for existing graduates, rather than providing an articulation route between occupational categories and/or for delivery of specified graduate competencies appropriate for commencement of practice. ACED is, however, working towards a classification of some 'stand-alone' masters[20] degrees to support a possible future 'program endorsement' process (see section 4.6).

In contemplating any future changes to professional engineering program structures, all stakeholders demand that the best features of current engineering education (including the current emphasis on design and project work, and industry experience) be maintained, and where possible, strengthened. They also demand that such features remain an explicit requirement for the accreditation of such professional engineering programs. Changes must be driven by clear definition of outcomes, driven in turn by deeper consideration of future occupational needs (including those of stronger research, innovation and potentially academic career pathways). Any changes must also be attractive to potential students, increase the participation of women, high-achievers, and other under-represented groups, and thereby contribute positively to the diversity of the engineering education system (see sections 6.3 and 6.4).

The idea that engineering education could, in some form, become a high demand generic degree (as some see law has) was endorsed by most groups in the study. Above all, it was agreed that the engineering community must understand students' motivations for professional engineering (and the reasons for engineering being a minority interest) before envisaging any major changes to existing programs, such as those outlined above.

2.4 Education for engineering technologists and engineering officers

Whilst professional engineers are expected to be the nation's engineering leaders and innovators, successful engineering enterprises require strong and integrated engineering teams which also include staff with capabilities that may be occupationally classified as (or observed) to match those of engineering technologists and engineering officers. Their roles (see Appendix 7) are described as being more 'practical' and 'hands-on', and less 'open-ended' and 'creative' than those of professional engineers. Consequently, engineering technologists and engineering officers tend to use lower levels of mathematics and basic science in practice, and need educational pathways that focus less on mathematics and science, but provide a greater intensity of technological material. The current lack of clarity in Australia around the engineering technologist and engineering officer occupational roles and respective graduate outcome standards underpins actions proposed under Recommendation 2.

The definitional and corresponding educational issues at the engineering technologist level are particularly complex. Work at this level, as defined by Engineers Australia, may include detailed design in a particular technology, or management and operation of technological systems. Some consulted within the study have argued that a large proportion of engineering work in Australia is actually at the engineering technologist level. Some submissions to the study have suggested that much of this work is undertaken by graduates of 4-year B.Eng. programs as part of their professional development, stating that "*being an engineering technologist in practice is the proper pathway to becoming a professional engineer*". Many employers holding this view also indicated that "*they would not employ 3-year qualified engineering technologists*". This combination of views denies, at least in part, the notion that there can be important and satisfying career roles for engineering technologists in their own right, a point addressed further below.

On the other hand, many employers welcome students in workplace experience placements after the third academic year of their B.Eng. degree, where they are very likely to undertake such "technologists"' work. Furthermore, some employers contributing to the study have stated that graduates from some B.Tech. programs are as effective as others who have B.Eng. degrees. This statement could be an indication that the additional education experienced by the latter group is not actually needed in the particular employer's workplace. It does not infer however, that an ideal B.Tech. study program should be designed as the first three years of a four-year B.Eng. program. This is clearly reinforced by the unique role statement and separate competency requirement set by Engineers Australia for the engineering technologist, identifying a career category quite distinct from that of the professional engineer. As a final and contrasting point, several consulted in the study questioned the need for a definable occupational role between that of technician (engineering officer) and the professional engineer, at least in Australia, while acknowledging that this role is well established in other countries.

Some, mostly engineering academics, consulted within the study expressed the view that technologists should be educated in the VET sector. As a degree qualified occupation, such provision would be outside the scope of the VET sector, except via developing Vocational Graduate Certificate and Diploma equivalence (see Table 1) and extending the scope of Engineers Australia accreditation.

Employers contributing to the study tended to quite comfortable with the occupational roles and traditional educational pathways for engineering officers. Within Australia, education at this level is provided mostly by the VET sector of tertiary education through public Technical and Further Education (TAFE) institutions. The Advanced Diploma qualification requires two years of post-secondary education (see Table 1), though historically a proportion of graduates at this level would have had prior trade qualifications, rather than entering directly from a full senior secondary school certificate. Several universities (mostly those that were Institutes of Technology or CAEs before the formation of the national unified system in the early 1990s) also awarded Advanced Diplomas in engineering and technology at this level. Under the provisions of the AQF, from 2004 most of these have been converted into Associate Degrees, opening to students further options for study and entry into engineering work, and universities the opportunity to offer further educational pathways.

Although at the same AQF level, the curriculum philosophy and outcomes of the two awards are quite different. The VET award system is unit-based around prescribed competencies, and designed to deliver an Advanced Diploma graduate with specific knowledge and workplace skills. The Associate Degree is, in contrast, a curriculum-based award, intended primarily to be a pathway to a full bachelor degree. However, the award should also provide its graduates with clearly defined sets of outcomes that have value within the relevant industry sector. Since there is an expectation that such graduates would use less mathematics and basic science in their work than professional engineers or even engineering technologists, together with the strong likelihood that students enrolling in such awards would have relatively lower school attainment, an Associate Degree would not normally be the first two years of a four-year engineering degree. Again, the role description and competencies defined by Engineers Australia for the engineering officer describe a stand alone career category quite distinct from those of the professional engineer and engineering technologist.

Although detailed consideration of Advanced Diplomas offered in the VET sector is beyond the scope of this study, several consulted in this study expressed deep concern with the ability of Advanced Diploma programs built on the training package – competency model to deliver outcomes appropriate to the engineering officer occupational category. Deep concerns were also expressed for the appropriateness of such programs as a foundation for articulation to higher levels of engineering study.

Emerging Issues

The engineering skills shortage (see Chapter 5) is not confined to professional engineers, but to all skill and qualification levels. This, together with the fact of high attrition from B.Eng. programs, suggests some urgency in building an engineering education system that best matches graduate outcomes (at all levels) to occupational needs, and produces significantly more graduates in total.

More detailed work needs to be undertaken on the value and need for Associate Degrees in engineering, with the principal driver being to better meet total employment demand for engineering officers. Similarly, it may be highly desirable to rethink and reposition improved educational pathways for engineering technologists, noting that higher education pathways (specifically 3-year B.Tech.) for engineering technologists have declined in number and student demand over the past decade.

The revision of occupation definitions and qualifications proposed in Recommendation 2 should draw on international expertise in the area, noting that Australian educated graduates of accredited B.Tech. degrees are currently recognised internationally by signatory jurisdictions to the Sydney Accord. Such work might well include consideration of improved nomenclature for the awards, noting current work in UK[21] that indicates that the title 'technologist' appears much less attractive to prospective students than that of 'engineer'.

Good industry practice should be a strong feature of education pathways for engineering technologists and engineering officers, and should remain an explicit requirement of accreditation for programs leading to such qualifications, possibly requiring extension of such programs from their current duration norms, particularly where this is supported financially by industry partners.

3 The outcomes and impact of the *Changing the Culture* Review

3.1 Introduction

(This section is based on a paper provided to ACED in December 2006 by Professor John Simmons and Emeritus Professor Alan Bradley)

The 1995-96 review was funded by the (then) Commonwealth Department of Education, Training and Youth Affairs (DETYA) and sponsored by three of the stakeholder bodies to the current project, ACED, Engineers Australia (at the time, IEAust), and ATSE, under their 'Tripartite Agreement'. The report of the review, *Changing the Culture: Engineering Education into the Future* (ref 1) was based on extensive consultative work of six task forces, covering the interfaces between engineering education and students, industry, the community and the profession; educational programs themselves, and institutional policies and systems.

Concerns with the engineering curriculum were identified in the Executive Summary, in the following terms:

> *"The present emphasis on engineering science resulting in graduates with higher technical capability, has often limited their appreciation of the broader role of engineering professionals."*

and later, on curriculum change and graduate attributes:

> *"Courses should promote environmental, economic and global awareness, problem solving ability, engagement with information technology, self-directed learning and life-long learning, communication, management and team-work skills, but on a sound base of mathematics and engineering technology."*

The report also focussed strongly on engineering practice, and the need to increase understanding of engineering in primary and secondary schools. The report contained 14 sets of recommendations intended to promote the engineering education system in higher education generally, and support collaborative action by all of the sponsoring stakeholders:

> *"to ensure that the momentum for change is not allowed to dissipate and that the intent of the Review is implemented".*

The stakeholders of *Changing the Culture* have been keen to use the opportunity of the current scoping study to reflect on the specific outcomes of that review, and to consider how change can best be wrought from broad discipline reviews such as the present one. The following paragraphs present a summary of each of the 14 recommendations and a comment on their outcomes. The greatest focus is on Engineers Australia's implementation of major changes to its accreditation policy and accreditation system for professional engineering qualifications that stimulated curriculum changes as proposed in the review. In the course of the present study most engineering schools have acknowledged the importance of the *Changing the Culture* review in driving such curriculum improvements in undergraduate education. The chapter concludes with a commentary on the requirements for effective implementation of change in the light of the *Changing the Culture* experience.

3.2 Commentary on each recommendation

Recommendation 1: Engineers must receive a broader education and be drawn from a wider range of backgrounds

There is almost universal agreement the first part of this recommendation has been addressed by integrating material on the social, economic and environmental context of engineering in most engineering programs. Almost all engineering degree programs now also include appropriate material and opportunities for students to develop and hone teamwork and communication skills. However, there are only very limited examples of exposure of undergraduate engineering students to multidisciplinary team activity. Current curriculum issues are taken up in more detail in Chapter 7.

The second element of this recommendation referred to attracting students into engineering from a wider range of backgrounds. As discussed in section 4.2, a large proportion of the growth of the engineering student population has been through the increasing number of international students, thereby increasing one dimension of diversity. The proportion of women commencing engineering studies increased steadily during the late 1990s, but has declined since 2001, as specific resources for women in science and engineering programs have also declined. Engineering schools have recruited vigorously to maintain their viability, changing and diversifying their program offerings. However, in general, little progress has been achieved in attracting a higher proportion of the most talented school leavers. Student demography and demand issues are discussed further in Chapter 6. This issue remains one of major fundamental concern.

Recommendation 2: Student intakes must be sufficient for Australian industry to remain internationally competitive.

This recommendation included a number of proposals.

Firstly, on the proposal that Engineers Australia and ACED continually monitor the demand for engineering graduates, the national picture – particularly as regards areas of skills shortage – has been monitored and published by Engineers Australia and others such as the annual graduate destination and starting[22] surveys published by the Graduate Careers Council (GCCA). APESMA's annual remuneration surveys[23] also provide very valuable data. Given these collections, ACED itself has not formally monitored graduate demand. Nevertheless, each engineering school has, of necessity, undertaken its own detailed assessment of demand and tracked graduate employment statistics, to maintain and realise its mission. Current graduate demand issues are discussed further in Chapter 5.

Secondly, the report proposed that ATSE and Engineers Australia call upon Government to articulate its policies for Australia to become significantly more internationally competitive in manufacturing, mining and agriculture, and in the technology of infrastructure development, and to reinforce the small and medium enterprises (SME) sector.

This appears not to have been addressed explicitly by either body, although in the normal course of their activities, they, and others, have supported engineering education initiatives in mining and manufacturing, in particular (see below), and in Cooperative Research Centres (see section 4.4).

The third proposal was to urge the Commonwealth to budget for an annual increase of 2% to 3% in engineering commencements over 1997 – 2000, and plan for more substantial growth in engineering activity in the first decade of the next century. No specific proposals were put to Government by the stakeholder group. However, engineering growth was addressed partly by initiatives under Backing Australia's Ability (BAA)[24] that were mostly intended to address the late 1990's rapid growth of the information and communications technology sector. Since 2003, provision was made for additional engineering undergraduate places in some universities to meet current graduate demand in areas such as mining engineering.

The proposals that Government and Engineers Australia encourage and support the professional development of migrant engineers and assist their transition into the community appear to have received no specific attention until fairly recently. As discussed further in section 4.6, many of the engineering schools have developed postgraduate programs with largely international student enrolments, and many of their graduates are ultimately seeking to immigrate.

Recommendation 3: Engineering courses must have clearly stated goals and outcomes and equip graduates for lifelong learning.

This recommendation had two strands. The first was a proposition that engineering schools should publish clear statements of their missions, and the objectives, specific outcomes and goals of their courses and base standards on the relevant best international practice.

Engineering schools have met this recommendation well. Over the decade, most universities have required such statements to be published routinely, and have required program and course revisions to be expressed in terms of their graduate outcomes. Engineering has maintained good international educational standards by a combination of mechanisms, including international benchmarking, international staff recruitment, student and staff exchanges, and participation in international curriculum networks, such as the CDIO[25] 'conceive, design, implement, operate' model (see section 7.3), strong academic participation in international engineering education conferences, and foundation membership by Engineers Australia of the International Engineering Alliance referred to earlier.

The second strand of this recommendation was at the core of the *Changing the Culture* review. This required –

> *"that engineering schools demonstrate that their graduates have the following attributes to a substantial degree:*
>
> - *ability to apply knowledge of basic science and engineering fundamentals;*
> - *ability to communicate effectively, not only with engineers but also with the community at large;*
> - *in-depth technical competence in at least one engineering discipline;*
> - *ability to undertake problem definition, formulation and solution;*
> - *ability to utilise a systems approach to design and operational performance;*
> - *ability to function effectively as an individual and in multi-disciplinary and multi-cultural teams, with the capacity to be a leader or manager as well as an effective team member;*
> - *understanding of the social, cultural, global and environmental responsibilities of the professional engineer, and the need for sustainable development;*
> - *understanding of the principles of sustainable design and development;*
> - *understanding of and commitment to professional and ethical responsibilities; and*
> - *expectation and capacity to undertake life-long learning."*

This set of graduate attributes formed the basis of the revised accreditation process (see below), and rapidly found specific expression in the statements of course and program outcomes of each engineering school. This process was reinforced by the introduction of similar sets of non discipline-specific 'generic attributes or qualities' in most Australian universities from the mid-1990s. Changing curricula to embed the development of all of the required attributes has been easier for some attributes than others, and has been achieved best where curriculum task and assessment have been strongly aligned with the particular attribute. Such alignment facilitates the ultimate expectation of this recommendation, that educators should be able to demonstrate that the attributes are achieved in individual students.

Regarding the non-technical, generic attributes in the list, most employers consulted in the study have agreed that today's graduates have superior verbal communication and team skills than their predecessors. On the other hand, many employers have referred to students having less ability to 'work from first principles'. These issues are explored further in Chapter 7. Carew and Therese[26] have led further work with Carrick Institute funding on defining better the graduate attributes required in engineering, and developing and promulgating related frameworks for assisting academics to construct sets of assessable learning outcomes[27].

<u>Recommendation 4: Professional accreditation systems must encourage innovation in course content and delivery.</u>

This recommendation proposed that –

"Engineers Australia work formally with ACED to develop a new accreditation system for engineering schools, with frequent review, that:

- *gives recognition to the significant changes facing the profession and to the critical and distinctive attributes needed by engineers for the future;*
- *ensures compliance with the requirements for courses as set out in Recommendation 3;*
- *stimulates innovation, experimentation, diversity and quality assurance both in courses and their delivery;*
- *is receptive to new and emerging technologies;*
- *includes assessment of the suitability of infrastructure, and the numbers, range of skills and academic and industrial experience of staff of engineering schools and their ability to achieve accreditation criteria;*
- *enables much of the accreditation process to be integrated with normal academic processes of the universities; and requires evidence of industry involvement in the development of curricula and delivery modes."*

The recommendation also proposed that Engineers Australia and ACED establish a Task Force to canvass the problems in introducing such a revised accreditation system, that would not disadvantage present students.

The intent of this recommendation has been achieved successfully through strong leadership by Engineers Australia and good collaboration with ACED. By having Engineers Australia routinely join ACED meetings and establishing a joint ACED/Engineers Australia Consultative Committee for the Engineers Australia Accreditation Board, a separate Task Force was not found to be necessary.

The final specific element of this recommendation proposed that engineering schools seek the advice of industry in the development and delivery of courses. Most engineering schools have intensified their industry advisory systems in relation to program and course development (see 4.9). This is a key issue in the revised engineering accreditation process, described below.

Engineers Australia published a new accreditation policy in 1997 based on the ten graduate attributes listed above, thereby directly reflecting the change imperatives recommended in the *Changing the Culture* report. The policy called upon the accreditation process to focus increasingly on graduate outcomes, with engineering schools developing internal systems and quality assurance processes to ensure graduates are adequately prepared to enter professional engineering practice. The 1999 *Manual for the Accreditation of Professional Engineering Programs* embodied the new outcomes-based approach to accreditation with criteria derived directly from the new policy, and was designed to promote change in the engineering education design and review cycle. The revised accreditation system came into operation in 1999-2000.

It was also recognised that, as the defining document for a process designed to promote change, the accreditation manual must itself continually evolve in accordance with the changing state of practice. In a continuing cycle of review and improvement, and in conjunction with ACED, Engineers Australia has subsequently redeveloped the accreditation criteria, system and processes for professional engineering qualifications, and their documentation culminating in the *Engineers Australia Accreditation Management System*, last updated in September 2008[28]. A parallel document system was produced in 2007 to cover the accreditation of programs at the engineering technologist level. The requirements and expectations that this accreditation system imposes on engineering education program design and implementation have been disseminated through the accreditation process itself as well as through regional workshops and publication in the engineering education domain, mostly at AaeE conferences.

Accreditation passes judgement on the appropriateness of educational objectives and targeted graduate capabilities, the integrity of the educational design and review processes and the means employed to deliver and monitor outcomes. The architects of the accreditation process believe that it is critical for the vitality of the profession that Engineers Australia accreditation system ***does not prescribe*** detailed program structures or content, but requires engineering education providers to have in place their own mechanisms for validating outcomes and continually improving quality. Thus program and curriculum diversity and innovation are encouraged, and the outcomes-based approach to accreditation was expected to drive an outcomes-based approach to educational design and review.

A further step, taken by Engineers Australia in 2004, was the development of the *National Generic Competency Standard for Professional Engineers*. This was intended to provide the primary assessment tool for the direct evaluation of fitness for entry to practice. The standard was designed for the assessment of individual candidates without a recognised professional engineering qualification (eg a qualification gained outside the Washington Accord signatory jurisdictions). The standard provides a comprehensive interpretation of the ten generic attributes and indicates performance expectations, organised under the headings of: knowledge base, general knowledge, and professional attributes. The standard can also serve as a template or guide for engineering schools to develop a detailed specification of targeted graduate outcomes for a professional engineering education program in any particular discipline.

Clearly, the recommendations in *Changing the Culture* have been a primary influence in the continuing evolution of the accreditation system for professional engineering and engineering technologist programs. Engineers Australia considers that engineering schools have genuinely responded to the challenges. There is evidence of cultural change in engineering education to broaden the focus of engineering education and deliver to all of the generic attributes, rather than concentrate on solely technical content. On the other hand, there is not strong evidence that this is being achieved in a systematic and holistic sense. Few engineering education programs are underpinned by a comprehensive specification of program objectives and detailed graduate outcomes that provide a clear understanding of the knowledge, attributes and capability targets for graduates in the particular discipline. There are too few examples of a systematic, 'top-down' educational design and/or review process where learning experiences and assessment measures are rigorously mapped and tracked against the specification of graduate outcomes for a particular program.

Developments and innovations in engineering education, although disseminated through professional communications, have tended to be localised and confined to individual universities. Some submissions to the current study have expressed concern that the balance of the modern curriculum has shifted too far from the traditional technical core of engineering, and that the accreditation process needs to be revised to reflect this. Others, particularly from industry, identified mismatches between engineering practice and education that also demand attention. Directions for curriculum development are discussed further in Chapter 7.

Recommendation 5: Each university should consider the viability of its engineering school

In its preamble to this recommendation, the review discussed the merits of having fewer large schools, and expressed "*doubts about the viability of some of the smallest regional schools unless they address niche markets*", but did "*not see a case for forced mergers or closures*", ref 1, p 42).

This recommendation proposed, nevertheless, that universities individually consider the viability of their engineering schools in terms of their local circumstances, context, performance, quality, and opportunities for effective rationalisation, networking with modern technologies, and sharing of resources. No coordinated mechanism was proposed to implement this recommendation.

As noted elsewhere in this report, most engineering schools have worked vigorously to attract international students and diversify offerings in order to remain viable. Nevertheless, internal university review processes and student demand trends have led to closure or suspension of engineering in a small number of institutions since 1996. Different trends have seen new engineering schools emerge at other universities. The total number of engineering schools in Australia remains basically unchanged. Examples of resource sharing, networking and collaborative engineering education are discussed elsewhere.

Recommendation 6: Internationally competitive Advanced Engineering Centres must be developed.

At the time of the Review there were three Advanced Engineering Centres funded under a Commonwealth scheme. The intention of this recommendation was to support representatives of ATSE, Engineers Australia and ACED in conjunction with industry representatives, to discuss with government the means of establishing and of financing further Advanced Engineering Centres that would be internationally competitive with world class expertise and facilities and maximise collaboration between universities, with the objective of promoting Australian industrial strength, research and development capability and improving the quality of formation of engineers.

In the event, the Tripartite group put early effort into addressing this recommendation, lapsing with withdrawal of Commonwealth funding for the AEC scheme itself. The educational award programs of the three AEC's themselves were mostly absorbed into the mainstream activities of their sponsoring universities.

Recommendation 7: Engineering schools must be prepared to form alliances and facilitate student mobility.

This recommendation urged engineering schools and their parent institutions to form alliances of mutual benefit, maximising access to and utilisation of scarce resources, and ensuring that students throughout Australia can choose from an appropriate range of high quality engineering programs and have mobility within the system.

Some progress has been made on the above recommendation, particularly with industry support. National curricula and resource sharing are the basis of major initiatives in the electrical power, and mining engineering and minerals processing areas, (see section 10.2). One state-wide alliance was formed to support the students aiming for the electronic manufacturing sector. Credit transfer arrangements have been improved to facilitate student mobility. Unfortunately, there is no standardisation of unit value and program structure across Australia's universities. The present study judges that there is much more scope for effective collaboration to improve engineering education, as discussed further in Chapters 7 and 8.

Recommendation 8: An effective and independent National Centre [for Engineering] must be established.

ATSE was designated to take the lead to press for the formation of this proposal for an independent as a 'think tank'. This appears not to have been actioned.

Recommendation 9: School and community liaison must be enhanced so that more students choose engineering.

Several initiatives and strategies were proposed for the stakeholders to lead, with industry assistance, to increase the level of engagement with the school sector.

There has been considerable activity in this area, with leadership from Engineers Australia, ATSE, and individual universities, some of which is reported elsewhere in this report. ATSE has undertaken a major initiative to lobby governments across Australia over the declining preparation of high school students in the enabling sciences, particularly mathematics and physics, for university studies in engineering and science. ATSE is strongly advocating improved support and resources for school science teachers. There is an urgent need to broaden further the engagement with the school sector, as discussed in section 4.8 and in the recommendations of the current project.

Recommendation 10: The four-year full-time course equivalent must remain the minimum requirement, but diversity must be encouraged.

This *status quo* recommendation for the minimum qualification standard for professional engineering has been maintained. As reported in earlier, there is now considerable diversity of program structures at this level. Furthermore, changes internationally, and in the focus groups in this study have opened discussion on future change to longer a minimum duration for professional engineering programs.

The recommendation also referred to deans taking action to reduce overloading of curricula and the formal class contact time required of undergraduate students in favour of alternative modes of learning and expanded opportunities for extra-curricular activity, and for engagement with industry. As discussed elsewhere in this report, these principles have been largely adopted, although there are concerns in some quarters that the reduction of contact time has been excessive and detrimental to graduates' outcomes.

The present study has also found that most employers find the revised undergraduate engineering education program structures do produce graduates with the desired range and balance of between professional and personal development attributes.

Many universities have, as proposed in the review, facilitated entry of students from non-traditional backgrounds through relaxation of prerequisite subjects, with bridging programs and flexible entry paths, and do provide articulation and credit transfer arrangements with industry, the VET sector, and other engineering program providers. The issue of further increasing enrolments into engineering from non-traditional pathways forms the basis of Recommendation 6 of the current study.

Recommendation 11: Staff profiles must balance teaching, research, professional practice and community skills.

This recommendation encouraged engineering schools to develop staffing profiles to include a balance of strengths in the areas of teaching and learning, research, professional practice, industry experience and community service, and adopt effective policies for the recruitment, development and reward of staff.

All engineering schools would now report significant progress on most operational aspects of this recommendation, while expressing continuing concern about the low numbers of women in academic positions in engineering, the increasing student-staff ratios (see section 4.3), and the impact of increasing emphasis on research, driven by the research quality and assessment exercise, as well as the emphasis on research-driven international university rankings. A critical issue is the lack of recent industry experience amongst academic staff. These and other related issues are taken up further in Chapters 4 and 8 of this report.

In relation to professional engagement of engineering academics, at its April 2006 Council Meeting, ACED resolved: "*That accreditation of an engineering degree program includes the requirement that an agreed minimum of the academic staff delivering the program have CPEng status or the equivalent, and that this requirement be implemented within five years.*" The present study did not identify any progress on this matter being pursued either by ACED or individual engineering schools.

Recommendation 12: Engineering schools must be prepared to collaborate to produce innovative courseware.

This recommendation proposed that engineering schools, with the support of Government and industry, establish a program to develop coalitions of engineering schools for the production of innovative engineering courseware.

This recommendation overlaps with Recommendation 7. No system-wide action was taken in this area, but a number of industry-driven collaborations occurred (see section 10.2). Government funding under the higher education Collaborative and Structural Reform (CASR) fund has been used to develop an educational resource network, the Advanced Engineering Capability Network (ACEN)[29], described in section 8.3.

Recommendation 13: There must be greater collaboration between the engineering schools and industry.

This recommendation urged ATSE, Engineers Australia and ACED to join with industry and Government in encouraging and assisting universities and companies to establish effective and enduring partnerships that involve and reward all participants, and remove unnecessary impediments to the formation and operation of such partnerships. Several specific areas of collaboration were proposed to improve the quality of students' educational experience, and increase the intensity and effectiveness of industry-university interactions.

The spirit of this recommendation has been taken up by engineering schools individually, with implicit endorsement of the stakeholders. As reported later (see sections 7.5 and 10.1), many very effective interactions have developed between the engineering schools and industry, and there remains a strong desire to increase the intensity of students' exposure to professional engineering practice through such collaborations, and to develop more systematic strategic collaborations, using the measures proposed under Recommendations 4 and 5 of the present report.

Recommendation 14: The sponsoring bodies must take immediate action to implement these recommendations

This recommendation proposed that - "*Engineers Australia, ACED and ATSE, in consultation with representatives from industry and engineering schools who are seen to be taking a leading role in various reforms: develop an immediate action plan and program for implementation, and monitor and report its progress to the sponsoring bodies and government, and consult with the Minister as appropriate on the recommendations.*"

The recommendation was not addressed as precisely as this formulation, and no formal action plan was produced for many of the other recommendations. The one notable exception was on accreditation, where Engineers Australia rapidly developed new policy and drove the introduction of the revised accreditation system to embrace the proposed changes to the engineering curriculum. Nevertheless, despite the lack of formal action on many of the recommendations, many of their intentions have been taken up by individual engineering schools.

In the course of developing its business, ACED members met with the Minister on several occasions, and the issues covered by the Review have remained on the agenda of the Tripartite meetings, culminating in their support for the present project.

A further specific proposal made under this heading was to review programs for engineering associates and engineering technologists offered in universities and in the vocational and education training sector that lead to Engineering Associate (now Engineering Officer) membership of Engineers Australia. No systematic work was initiated on this topic. The issue of occupations and education for these members of the engineering team is being addressed further in the current review.

3.3 General observations on the Changing the Culture review

Engineering deans have commented that the *Changing the Culture* review has had a profound impact on Australia's engineering schools, largely through Engineers Australia's introduction of the revised accreditation process. Importantly, most engineering deans generally regard accreditation positively for focussing on the right outcomes, and not stifling innovation, and for some, accreditation is a significant lever within their institutions. The introduction of the accreditation system for engineering that focussed on graduate outcomes and internal quality assurance systems was timely with respect to universities developing their own such systems, and the introduction of the Australian Universities Quality Agency[30] (AUQA). The documentation required for engineering accreditation now aligns with what is required within most universities' own systems. The focus on accreditation driving change is similar to the assessment driver for changing curriculum content and student learning, and for influencing the disposition of resources.

Engineers, in both universities and in industry, with particular interests in extending and embedding sustainability in the engineering curriculum and strengthening the less-technical domains of the generic attributes have also commented on the enduring value of having the *Changing the Culture* document as an authoritative endorsement of their concerns. Many in these groups would also argue that curriculum change as proposed by the review has not been embedded nearly as far into the thinking of engineering schools as it should be.

Alongside much innovation, the content and methodology of many engineering courses and programs have not changed substantially over the decade. Neither has the demographic profile of student intake substantially changed. These points are evidence of the culture of engineering education ***not*** changing as much as the architects of *Changing the Culture* intended.

The lack of nation-wide progress on several of the recommendations, particularly those that propose inter-institutional collaboration, is partly a result of the realities of university autonomy and competition. Collaboration occurs where there are clear incentives and benefits to all partners, and there are good examples of collaboration described elsewhere in this report.

A more general observation that has relevance for the present study is that proposed actions for change will be more widely implemented if four elements can be brought together: vision, leadership, stakeholder engagement and resources. It is quite clear from the present study that much of the curriculum innovation that has occurred in individual institutions has had all four enabling elements present. They were also there for the introduction of the new accreditation system. It is with this in mind that the proposed actions from the present study have identified leaders and stakeholder groups, and sets of measure and milestones against which success may be evaluated.

Finally, it may be observed that the engineering education community appears to be comfortable with undertaking periodic reviews of this nature. It is within the nature of the engineering discipline itself to be seeking better outcomes from any operation. Engineers have core abilities to analyse needs, and design and implement solutions, and tend to treat curriculum as an engineered artefact. That there are already very many different implementations of engineering programs is perhaps a reflection of a restless engineering spirit, as well as expression of the intention to provide programs that suit specific needs. But as noted above, many would conclude that the culture of Australian engineering education has not changed profoundly over the decade. One supportive participant in a focus group questioned the ability of Australia's engineering profession to undertake substantial reform through internally driven processes.

4 Australia's higher education engineering schools: 1996 – 2007

4.1 Introduction: the higher education context

Changing the Culture provided a framework for the development of Australia's engineering education enterprise, particularly for entry-level professional education. In the decade since its publication Australia's universities have been subject to many other changes and forces.

Two Commonwealth government measures that have impacted strongly on the engineering schools were raised as critical by all of the engineering deans:

- the decision in 1996 to not increase operational funding in line with the Australian cost-price index, putting pressure on universities' funded resource base;
- the decision to introduce the Research Quality Framework (RQF) as a basis to direct future research infrastructure funding from 2009. Although the present Government does not intend to implement the specific methodology proposed, considerable effort was expended within the universities to prepare for the RQF.

Many other factors have influenced the engineering education sector over the decade, including:

- Australia's growth in the international student market, with engineering schools participating strongly in this growth, and many becoming heavily reliant on the corresponding fee income;
- several Commonwealth programs that have increased funding for science, technology and engineering education and research, such as under Backing Australia's Ability, and later though the CASR program;
- the introduction of the Learning and Teaching Performance Fund (LTPF), that uses student progress and graduate outcomes data to differentially fund universities, requiring engineering schools to pay closer attention to students' progress and their perceptions of teaching.

One outcome of these changes is that the Australian university sector has grown less dependent on its Commonwealth Grant Scheme (CGS) funding support to teach undergraduate and some postgraduate programs. In 2006 the higher education sector as a whole received less than 25% of its total revenue[31] from this specific source. Through the Higher Education Contribution Scheme (HECS) students are contributing (mostly through deferred taxation) a higher proportion of university operating costs than a decade ago. For many engineering schools international student fees and competitive research funding have become equally as important as the revenue for teaching Australian students.

These five points, and others, have impacted on Australia's engineering schools in different ways, intensifying the diversity of the system. Two further issues, however, have dominated the engineering schools' ability to develop and respond to industry's demand for domestic graduates, and both featured very strongly in submissions and consultations with academic groups:

- the steady decline in the proportion of Australian school students taking the higher levels of study in mathematics and physical science, thereby reducing the pool of school leavers from which engineering students are drawn (see section 6.2);
- the decreasing proportion of engineering graduates seeking to progress to higher degree research and towards academic careers, thereby weakening prospective staffing in engineering schools (see sections 4.4 and 8.1).

The following sub-sections provide data on student and staff numbers in engineering for the period since 1996. Student numbers growth (section 4.2) has been primarily international, while staffing increases (section 4.3) have been primarily in research-only positions. The student profile section provides some data and commentary on the diversity of entry levels of domestic undergraduates and attrition from their programs. A brief discussion of engineering research is provided in section 4.4. The concluding subsections of this profile comment on the breadth of undergraduate programs across the system, and the growth of international students and postgraduate programs. In all of these areas, the submissions and consultations identified important emerging issues, many of which are addressed in the recommendations. Curriculum, industry collaboration and student outreach are discussed in later chapters.

As a discipline-based study, the focus has been on Australia's engineering education as a whole, rather than individual universities. In reality, however, the system is the combination of largely independent engineering schools, each situated in a formally independent and autonomous university. As such, each university and engineering school has its own particular mission that reflects its particular locality, employer community and institutional history. Whilst much of engineering practice transcends state and national borders, and is truly a global discipline, such diversity is important. The consultations undertaken in this study have, for instance confirmed the importance of the engineering schools outside the major cities in meeting employment demand in regional areas (see section 4.5).

A second point of diversity across the system is the location of the engineering school in each university's academic structure. Since 1996, many universities have made internal changes to their academic organisations, generally to reduce the number of academic entities, such as 'Faculties', 'Schools' and 'Departments', merging them into larger academic structures with greater discipline diversity. The current disposition of engineering schools and their accredited programs is provided in Appendix 8. More often than not, contemporary academic structures combine engineering with computing and information technology, and often mathematics, as biological sciences increasingly dominate faculties of science. The formerly common 'Faculty of Engineering' organisational entity is now rare.

Appendix 8 also summarises the academic substructure for engineering in each school. In many instances these are 'Schools' or "Departments' based on engineering disciplines, but in others, disciplines such as civil engineering operate in multidisciplinary schools covering several of the professions that operate in the built environment. The loss of identity of engineering in these emerging structures deeply concerns some members of the profession, while others see advantages in multidisciplinary settings. Other data in Appendix 8 reveal the wide diversity of Australia's engineering schools in terms of size, discipline coverage, and international student participation.

4.2 Engineering student data: 1996 - 2006

Tables 2 and 3 provide data on total enrolments (persons) and commencements in engineering programs at each award level. Each of the tables also shows the proportion of international students and female students within the total, for each award level.

The data in Table 2 shows that undergraduate teaching dominates the effort of engineering schools, being 78% of all student enrolments in 2006. Since 1996, undergraduate enrolment growth of 25.5% was overshadowed by postgraduate coursework growth of 128%, most of which is from international enrolments. In fact the number of domestic postgraduate coursework students has changed very little, from 4,029 to 4,430 over that period. Similarly, research enrolments are increasingly international.

Table 2 Total enrolments in engineering awards, 1996 – 2006, with proportions of women and international students at each award level.

award level	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
doctorate	2,319	2,321	2,371	2,449	2,531	3,245	3,374	3,699	3,985	4,110	4,199
% female	15.7	16.6	18.3	18.8	20.7	21.4	20.7	20.4	20.8	20.6	21.1
% international	23.6	22.3	21.3	20.5	19.3	21.4	22.3	23.3	24.7	27.0	30.1
research masters	1,313	1,261	1,181	1,124	1,044	1,157	1,212	1,184	1,287	1,253	1,214
% female	17.1	18.3	18.0	18.1	15.6	17.0	16.9	18.8	18.7	21.1	20.8
% international	19.4	18.5	18.4	18.1	18.6	20.3	21.5	23.7	28.0	32.0	35.3
coursework masters	2,314	2,316	2,200	2,246	2,414	3,799	4,706	6,584	7,102	7,178	6,656
% female	12.5	14.0	14.7	16.7	16.3	18.2	17.0	15.7	16.2	16.6	16.7
% international	24.3	26.9	29.5	36.3	43.8	53.3	56.3	65.8	67.7	68.4	65.3
other postgraduate	1,715	1,777	1,337	1,265	1,342	2,163	2,228	2,273	2,263	2,456	2,546
% female	14.5	15.8	17.0	16.1	18.1	17.4	18.1	16.4	17.4	16.8	18.5
% international	8.5	8.5	11.5	9.2	18.0	15.1	17.5	11.4	11.4	15.6	16.7
bachelor degree	40,085	41,468	42,063	42,766	42,791	46,891	48,202	49,402	49,441	48,851	49,676
% female	13.8	14.0	14.2	14.5	14.9	15.5	15.6	15.4	15.0	14.7	14.5
% international	10.3	11.3	11.9	13.0	14.0	17.2	19.7	22.2	23.5	24.0	24.3
associate degree*	942	245	195	653	593	741	862	806	827	963	1,238
% female	6.9	9.0	7.7	7.7	6.6	5.0	9.0	10.2	7.7	11.0	16.1
% international	2.8	0.0	6.7	2.0	3.0	4.3	11.5	12.0	14.1	19.6	22.7
other undergraduate	26	610	576	72	98	287	654	710	612	546	636
% female	7.7	6.4	7.1	37.5	29.6	13.2	9.5	11.0	7.2	15.4	17.9
% international	0.0	2.5	1.0	4.2	4.1	2.1	2.0	10.0	8.5	11.0	13.2
Total	48,714	49,998	49,923	50,575	50,813	58,283	61,238	64,658	65,517	65,357	66,165
% female	13.8	14.2	14.4	14.8	15.3	16.0	15.9	15.7	15.5	15.4	15.4
% international	11.6	12.5	13.1	14.3	15.7	19.5	22.3	26.1	27.8	28.8	28.5

* including university Diploma awards, pre 2004

Data: DEEWR via Engineers Australia

The data also show that the proportion of international enrolments in undergraduate programs has more than doubled over the period, to nearly 25% in 2006. The proportion of women in all engineering award programs increased steadily to 16% in 2001, but has declined since. However, the proportion of women in postgraduate research awards has been greater than 20% for several years, and in postgraduate coursework continues to increase, both trends being a consequence of the proportions of women amongst the growing international student cohorts. Section 5.3 addresses the issues around the attraction and recruitment of more women into engineering programs.

Table 3 shows the number of commencing enrolments at each award level. The proportions of female and international students broadly track total enrolments. For the undergraduate awards, students with advanced standing commence into study years later than the first program year. Almost all of the post 1996 growth in undergraduate commencements has been in international students: from 1,650 to 4,156, compared with domestic undergraduate commencements increasing from 10,944 to 11,140. There is now some evidence of sustained increase in domestic enrolments from the low point in 2005.

Table 3 Commencing enrolments in engineering awards, 1996 – 2006, with proportions of women and international students at each award level.

Award level	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
doctorate	592	671	655	655	732	771	840	872	951	822	847
% female	20.3	18.3	22.0	19.7	23.9	22.7	21.7	19.8	21.1	19.8	23.3
% international	24.2	23.8	25.0	25.2	24.0	30.7	26.9	29.5	27.8	33.1	42.6
research masters	499	542	450	443	421	419	483	454	519	429	392
% female	13.4	14.8	14.2	14.9	11.2	12.4	15.3	16.7	15.0	14.0	11.7
% international	25. %	20.5	25.3	22.1	26.6	28.9	29.0	34.8	39.1	41.3	45.4
coursework masters	1,081	1,107	1,130	1,300	1,497	2,103	2,752	3,857	3,751	3,455	3,238
% female	14.0	14.4	14.6	16.5	14.6	17.5	16.8	14.9	16.3	17.0	16.6
% international	33.4	37.1	38.5	49.3	54.5	62.1	63.4	73.9	74.3	74.6	70.9
other postgraduate	1,114	1,127	828	815	875	1,299	1,222	1,243	1,157	1,363	1,322
% female	13. %	13.2	13.6	11.9	13.5	14.9	14.3	12.8	14.4	14.0	15.0
% international	10.7	10.4	14.6	11.2	20.9	17.0	21.0	11.9	14.0	21.6	24.4
bachelor degree	12,233	12,763	12,514	12,974	12,676	14,160	14,137	14,369	13,846	13,698	14,142
% female	13.9	14.0	14.4	14.9	15.5	15.5	15.1	14.9	14.4	14.1	14.5
% international	13.4	14.0	12.9	15.8	17.6	23.8	27.3	29.8	28.4	27.6	27.3
associate degree*	335	76	114	293	241	269	412	322	336	568	602
% female	8.1	5.3	5.3	8.9	6.2	5.6	13.3	6.5	3.3	15.3	18.8
% international	2.4	0.0	11.4	3.1	6.6	6.3	18.7	8.4	12.5	26.2	27.2
other undergraduate	25	246	261	70	90	242	583	662	565	481	553
% female	8.0	2.8	6.1	38.6	31.1	13.2	9.4	10.4	6.2	15.4	17.4
% international	8.0	1.6	0.4	4.3	4.4	1.2	4.8	7.1	6.4	17.9	23.9
total commencing	15,881	16,534	15,954	16,552	16,534	19,266	20,432	21,782	21,128	20,819	21,099
% female	13.9	14.0	14.4	15.1	15.5	15.7	15.4	14.7	14.6	14.8	15.3
% international	15.1	15.6	15.5	18.5	21.4	27.4	30.9	35.4	35.0	34.8	34.0

* including university Diploma awards, pre 2004 Data: DEEWR via Engineers Australia

With the widely acknowledged need to increase engineering graduate numbers at all award levels, it is instructive to compare domestic engineering commencements with those of other discipline areas. Table 4 shows how engineering has fared in attracting domestic students (at all award levels) in comparison with other discipline areas. The precise fields of education included in each classification changed between 2000 and 2001, making compilation of accurate data over the decade difficult. Nevertheless, the broad trends are clear: domestic engineering commencements have not changed substantially over the period when domestic enrolments into award programs have increased by nearly 17%. In 2006 only 5.4% of all domestic commencing enrolments were into engineering, compared with 6.1% a decade earlier. Prior to 2001, enrolments into computer science and information technology programs were included within the science total, and were growing rapidly. It is somewhat ironic that since IT enrolments have been reported separately, their decline has been dramatic. The areas of enrolment growth have been Health (47%) and the combination of law, business, arts and society (27%).

Table 4 Commencing enrolments (all award levels) by Australian (domestic) students enrolling in award programs, 1996 – 2006.

year	Engineering & Surveying/ Engineering & Related Technologies	Health	Science/ Natural & Physical Science	Information Technology (from 2001)	Law, Business and Society (composite)	total commencing award programs
1996	13,493	26,730	32,785		115,062	219,817
1997	13,960	26,775	35,774		123,373	231,402
1998	13,520	26,892	34,961		120,667	226,238
1999	13,482	27,314	36,707		123,357	230,359
2000	13,026	27,687	37,278		125,246	234,399
2001	14,031	29,969	20,999	17,436	135,454	244,491
2002	14,171	31,834	20,610	16,085	139,678	252,932
2003	14,033	31,256	20,717	13,553	137,184	246,726
2004	13,742	32,057	21,355	11,122	134,158	241,208
2005	13,579	35,492	20,715	9,277	141,544	248,356
2006	13,931	39,283	20,943	8,198	145,742	256,382

Data: DEEWR higher education statistics website

Table 5 provides graduation data for 1996 to 2005. The bachelor degree category has been separated into three-year and four- or more- year categories to show how small the graduating numbers are from the three-year programs.

For each program, graduation numbers follow commencing enrolments with a delay corresponding to the duration of the program, minus the number of students who, for whatever reason, do not complete the program, and make up what is referred to as 'student attrition'. Taking reasonable estimates of award program duration into account, the differences between the proportions of graduating to total students in any award, appears to show that international students are more likely to graduate than domestic students, and female bachelor's degree students complete at a slightly higher rate than the class as a whole. Further data on attrition are provided later.

Knowing the distribution of students between engineering disciplines is also important in relation to understanding student choice, and meeting industry's graduate demand. Table 6 provides data for four-year graduates of Bachelor of Engineering programs for

2001 – 2005 for the main areas of engineering. This table also shows the proportion of graduates of Bachelor of Engineering programs of more than four years duration, thereby indicating the number of dual degree graduates in each discipline area. Graduates from degrees of unknown duration (typically 250 per year) have been aggregated with the four-year group.

Table 5 Graduations from engineering award programs, 1996 – 2005, showing the proportions of women, international students graduating at each award level. Three-year and four-year bachelors graduate numbers are shown separately.

Award level	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
doctorate	413	471	438	436	474	420	480	528	570	637
% female	12.6	12.1	16.7	15.6	16.2	19.5	16.7	21.0	19.3	19.9
% international	29.5	30.1	25.8	26.6	25.1	23.1	20.6	20.5	26.1	29.0
research masters	237	261	230	195	189	206	185	194	220	208
% female	20.3	16.5	16.5	22.1	26.5	20.9	20.5	20.1	17.7	22.6
% international	24.9	23.0	28.7	26.2	24.3	29.1	22.2	23.7	33.2	36.1
coursework masters	831	949	972	1059	1052	1552	1695	2379	2587	2934
% female	10.6	13.9	13.1	13.2	17.7	19.7	18.5	16.3	17.0	17.2
% international	38.9	37.5	41.7	48.9	56.5	59.0	63.2	72.1	75.1	78.4
other postgraduate	630	698	651	556	513	517	484	556	528	558
% female	13.5	13.6	11.7	15.5	13.1	15.5	15.9	17.6	18.6	18.3
% international	13.5	22.8	19.7	6.8	17.3	20.9	31.0	26.1	22.5	34.9
4-year bachelors	6,008	6,330	6,559	6,507	6,613	6,790	6,486	6,856	7,251	6,876
% female	14.2	14.9	14.8	14.9	15.1	17.3	17.8	18.0	17.6	17.2
% international	12.0	12.7	15.4	19.1	21.5	19.9	21.3	23.6	25.2	28.1
3 –year bachelors			included in above			929	983	972	949	1,200
% female						14.6	14.0	12.9	13.3	17.1
% international						33.4	37.4	39.1	41.6	38.9
associate degree*	206	76	74	154	120	184	222	191	182	190
% female	3.9	13.2	5.4	10.4	5.0	2.7	4.5	13.1	18.7	7.4
% international	5.8	1.3	10.8	5.8	6.7	9.2	16.2	18.3	31.9	25.8
other undergraduate	11	99	76	16	9	113	297	264	456	191
% female	0.0	5.1	1.3	6.3	0.0	3.5	4.7	6.4	0.7	5.2
% international	0.0	4.0	1.3	12.5	0.0	0.9	1.7	19.7	2.6	9.4
total graduates	8,336	8,884	9,000	8,923	8,970	10,711	10,832	11,940	12,743	12,794
% female	13.6	14.5	14.4	14.8	15.5	17.1	16.8	17.1	16.7	17.1
% international	15.8	17.2	19.2	22.2	25.4	26.7	29.1	34.3	35.9	40.8

* including university Diploma awards, pre 2004 Data: DEEWR via Engineers Australia

Compiling these data from DEEWR graduates data by ASCED[32] Field of Education code has revealed some disparities between the discipline names used for engineering degrees within the profession, and those used by the ASCED classification. This may be the main reason for the high proportion of awards put in the 'other' or 'not classified' categories; and the specific absences of software engineering and systems engineering in the ASCED codes may warrant future attention.

Table 6 Bachelor of Engineering degree graduations by area of engineering, 2001 – 2005, showing proportions of female, international students and graduates from programs of more than four years duration.

engineering area	2001	2002	2003	2004	2005
mechanical, industrial & manufacturing	1,134	1,086	1,147	1,222	974
% female	10.6	10.1	11.3	9.6	8.6
% international	25.2	25.9	31.1	32.9	38.9
% from degrees longer than 4 years	29.6	17.9	16.1	15.3	7.5
process and resources	735	791	717	843	613
% female	27.1	32.1	30.5	30.7	29.2
% international	14.1	17.4	21.8	22.8	28.9
% from degrees longer than 4 years	13.5	23.9	21.6	26.1	17.6
Civil	1,120	974	966	889	789
% female	18.4	18.3	15.2	17.5	16.7
% international	17.3	16.0	15.7	16.4	20.0
% from degrees longer than 4 years	15.7	10.8	16.9	13.9	12.4
electrical & electronic	2,121	1,968	2,366	2,451	2,116
% female	10.3	10.3	10.4	10.6	8.6
% international	25.0	27.3	30.6	31.3	31.9
% from degrees longer than 4 years	22.6	16.2	14.7	17.7	16.4
aerospace	196	187	160	226	223
% female	11.7	15.0	15.0	11.5	15.2
% international	11.7	15.5	10.6	11.5	20.2
% from degrees longer than 4 years	16.3	8.6	1.9	15.9	10.3
Maritime	13	12	2	27	12
% female	0.0	0.0	0.0	3.7	0.0
% international	15.4	0.0	0.0	11.1	8.3
% from degrees longer than 4 years	0.0	0.0	0.0	0.0	0.0
Environmental	181	132	128	122	78
% female	42.5	39.4	48.4	29.5	41.0
% international	4.4	3.8	7.8	10.7	11.5
% from degrees longer than 4 years	17.1	16.7	27.3	20.5	10.3
Biomedical	54	59	44	28	29
% female	35.2	35.6	38.6	35.7	65.5
% international	7.4	1.7	4.5	10.7	0.0
% from degrees longer than 4 years	18.5	47.5	43.2	46.4	51.7
Other	1,115	1,115	1,204	1,297	1,887
% female	18.7	15.4	18.3	16.5	17.3
% international	17.1	18.5	15.8	21.0	25.2
% from degrees longer than 4 years	27.4	26.4	36.5	39.9	36.4
total graduates	6,669	6,324	6,734	7,105	6,721
% female	16.1	16.1	15.8	15.2	14.7
% international	20.1	21.4	23.9	25.7	28.6
% from degrees longer than 4 years	22.0	18.5	20.0	21.9	20.2

Data: DEEWR via Engineers Australia

With more than a quarter of the graduations recorded as 'other' for 2005, conclusions about trends between discipline areas cannot be more than tentative. Furthermore, there are some unresolved numerical disparities between the total graduation data and the proportion of females as shown in Tables 5 and 6.

The data appear to show declines in graduate numbers from mechanical and civil engineering and a peak in the electrical and electronic area around 2003-4, all related to the information technology boom in the late 1990s. Since around 2003 these trends changed markedly, with higher proportions of engineering students electing to study civil, mechanical and resources engineering than the electronics and computing areas.

In summary, ***international students*** are more likely to be graduates from mechanical engineering and allied areas and electrical and electronics engineering, than from biomedical or environmental engineering. ***Women*** are more likely to graduate from biomedical, environmental, and process (including chemical) engineering, than from mechanical or electrical. ***Dual degrees*** are most likely to be held by graduates of biomedical engineering, environmental and chemical engineering.

Attrition from engineering programs

An area of much discussion in the consultation process was attrition of students from engineering programs, and the subsequent 'apparent loss' that that represents to the engineering profession. The data in Table 7 show the aggregate figures for commencements and graduations for domestic students in Bachelors degrees, using the data in Tables 3 and 5. A first-order estimate of attrition can be made by assuming the graduation numbers in any particular year were drawn from commencing students four years earlier. For example, the 1998 graduation success rates are assumed to have commenced study in 1994.

In practice, of course, graduates may well take less time to graduate (if they are on 3-year programs or have advanced standing), or longer, particularly if they are taking dual degree programs, or studying part-time. The graduation success rates computed in this manner for longer study periods than the notional four years are not very different from these figures, ranging between 49 - 55% for males, and 55 – 73% for females. Part of the volatility in these figures is the variation of commencing numbers. It is clear, however, that, on average, male Australian engineering students have about 52% likelihood of successful graduation from a bachelor level engineering program, and females about 60%.

Table 7. Estimates of graduation success rates for domestic students enrolling in bachelors degrees in engineering, 1994 – 2005.

student cohorts	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
commencing males	8,839	8,937	9,150	9,432	9,352	9,335	8,905	9,148	8,792	8,667	8,574	8,663
females	1,397	1,400	1,446	1,550	1,543	1,586	1,537	1,638	1,486	1,422	1,336	1,257
graduating males	4,164	4,562	4,533	4,700	4,720	4,503	4,418	5,034	4,753	4,847	5,005	4,732
females	695	730	756	824	830	761	772	1,027	968	984	975	948
4-year graduation success rates, % males					53.4	50.3	48.2	53.3	50.8	51.9	56.2	51.3
females					59.4	54.3	53.3	66.2	62.7	62.0	63.4	57.8

Data source: DEEWR via Engineers Australia

International student success rates cannot be calculated on this basis, due to the much higher variation in advanced standing given to such students for their prior studies, and the rapid growth in student numbers. International students, on average, have higher graduation success rates than their Australian contemporaries.

These observations on attrition are further substantiated by the success rates and retention rates used by DEEWR for modelling university program profiles, and monitoring university performance. DEEWR data defines 'success' as the ratio of courses passed to courses enrolled in any academic period. Table 8 summarises these rates, and shows that, on average, women have a 4% higher success rate than men, and part-time students have at least 10% lower pass rates than their full-time colleagues. Of course, students who do not pass courses are normally permitted to retake them, and extend their time to graduation. 'Retention' rates, also shown in Table 8, quantify the proportion of students who either complete the study year successfully, or progress to a subsequent year of study. These average success rates and retention rates can be used to estimate the average graduation success rate. Simplistically, for a nominal full-time program of four years duration, the mean retention rate of 88.5% (as for male domestic students) implies an average successful graduation rate of 61% ($0.885^4 = 0.61$). The average graduate success rate would be less than this, since on average, less than 100% course success also implies a longer completion time than the four year minimum. Thus the overall graduation success rates shown in Table 7 are broadly consistent with these figures. However, these data also indicate that a program catering for students in predominantly part-time study mode would show much lower success rates than this figure.

There are, in fact, considerable variations in the success and retention rates between engineering schools and between program years. Success and retention rates in early years of engineering programs tend to be lower than in later ones, due to the mathematically intensive courses that are, in effect, gatekeepers to student progress.

Table 8 Mean course annual success and retention rates for students in undergraduate engineering award programs averaged over 2001 – 2006, by gender, enrolment status and study pattern.

	domestic students				international students			
	male: full-time	male: part-time	female: full-time	female: part-time	male: full-time	male: part-time	female: full-time	female: part-time
success rates, mean number of students/year	26,588	6,192	4,783	767	7,453	1,381	1,233	172
mean success rates	85.9%	73.8%	90.0%	77.8%	86.1%	77.0%	90.8%	80.9%
retention rates, mean number of students/year	23,342	5,102	4,130	587	6,014	1,024	1,334	128
mean retention rates	88.5%	68.3%	91.0%	68.8%	90.9%	65.3%	92.3%	67.7%

Data: supplied by DEEWR

The final point that needs to be made is that at the individual level there can be many reasons for leaving an engineering program before graduation. At least a proportion of non-graduating students are likely to be working in engineering roles in industry. Others may have transferred to degree programs in science or business. There is a need to understand the dynamics of attrition further.

Commencements into engineering from secondary school

A further concern raised by educators and industry in the consultations is the entry standard of commencing students, particularly the majority who gain admission to higher education on the basis of their senior secondary education certificate. Many academics referred to the "*tyranny of the tertiary entrance rank*" as dominating students' choice of higher education program. The inference is that the most able students are encouraged to take school subjects that maximise their TER (Tertiary Entrance Rank) or UAI (University Admission Index), rather than study subjects they are most interested in, and also choose a university program that does not 'waste' the status of their earned rank. Thus a student with a UAI of 95 might not consider applying for an engineering program with an advertised UAI cut-off (or equivalent) of less than 90. It is thus informative to have data on the range of UAI's published within the sector for Bachelor of Engineering and other programs. Rather than identify individual universities, the compilation in Table 9 uses the established groupings of universities used in Australia, plus 'regional" and 'other' categories explained in Appendix 8.

Table 9 Published UAI cut-off ranges for entry to Bachelor of Engineering degrees and dual engineering degrees in university groupings (see Appendix 8) in comparison with selected other programs, for admission in 2008.

university grouping	UAI for single B.Eng.	UAI for dual engineering and science	UAII for dual engineering with management or commerce	typical higher UAI rank required for law	typical higher UAI rank required for management	typical higher (lower) UAI rank required for science*
ATN	70 ~ 98	73 ~ 85	74 ~ 92	12	5	(13)
G8	80 ~ 99	80 ~ 96	80 ~ 95	17	10	(4)
IRU	62 ~ 82	70 ~ 95	67 ~ 85	20	0	(6)
NewGen	51 ~ 88	n/a	88	20	5	0
regional	60 ~ 75	75 ~ 78	78	n/a	n/a	0
Other	54 ~ 78	60 ~ 86	64 ~ 80	12	2	0

Data: state tertiary entrance handbooks, websites and university web-sites

The published very high UAI cut-offs for a small number of single engineering programs apply to programs with restricted entry. In general, dual science-engineering and dual engineering-management or commerce programs require higher cut-offs than that for single engineering degree programs in any given university. Single science degrees typically have lower cut-off ranks than engineering in the ATN, G8 and IRU groups. Single management degrees tend to have higher cut-offs than engineering, and law invariably has a much higher cut-off rank, nowhere less than 10 ranking points higher than engineering at the same institution.

These cut-offs do not infer that all the students in a particular program gained UAI ranks near to the cut-off value. In practice all engineering schools have student cohorts with wide distributions of aptitude for engineering, as well as previous academic attainment. The implications of student perception of cut-off ranks and their impact on how engineering views itself as a prestige profession are discussed further in sections 4.5 and 4.8.

4.3 Staffing numbers in engineering: 1996 - 2006

Staff are the principal resource through which engineering education is delivered, and the consultations focussed strongly on the necessity of adequate academic and support staffing. Since 1996 the staffing profiles in engineering schools have changed significantly, as summarised in Table 10.

Historically, the standard academic role is 'teaching & research'. Staff in such positions normally have 'continuing' contracts of employment, confirmed after a probationary period, equivalent to, but less rigorous than the USA's tenure system. The small number of 'teaching-only' positions is declining. 'Research-only' positions are mostly limited-duration contract positions (usually titled 'research assistants' at the lower academic level, and as 'research fellows' – junior, senior and professorial – at the higher levels), funded by research projects, although, with the formation of research centres and institutes, an increasing number of these are of 'continuing' form, sometimes with their incumbents having a fallback teaching & research position.

The most notable features of the decade to 2006 are:

- the high growth of research-only staff numbers, with this category being 40% of the total academic staffing complement in engineering in 2006;
- the decline in the number of support staff, with the data and consultations inferring that that the decline has been mostly from workshop and laboratory technical support functions;
- the near doubling of female academic staff over the period, with this increase higher in research-only roles rather than in teaching ones.

Table 10 Full-time equivalent (FTE) staffing employed in engineering schools, 1996 – 2006, by gender and academic role.

staff groups	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
academics, male											
teaching-only	62	70	71	70	63	63	60	53	66	57	41
research -only	474	527	479	522	503	636	686	753	834	834	915
teaching & research	1,687	1,637	1,485	1,498	1,399	1,480	1,477	1,488	1,464	1,520	1,478
sub-total, academic males	2,223	2,234	2,035	2,090	1,965	2,179	2,223	2,294	2,364	2,411	2,434
academics, female											
teaching-only	2	6	3	5	4	3	3	4	12	1	1
research -only	83	98	63	94	103	145	169	183	195	190	225
teaching & research	99	103	111	127	125	152	156	155	157	181	171
sub-total, academic females	184	207	177	226	232	300	328	342	364	372	397
total academics	2,407	2,441	2,212	2,316	2,197	2,479	2,551	2,636	2,728	2,783	2,831
% research-only	23.1	25.6	24.5	26.6	27.6	31.5	33.5	35.5	37.7	36.8	40.3
% female	7.6	8.5	8.0	9.8	10.6	12.1	12.9	13.0	13.3	13.4	14.0
support staff											
male	1,263	1,236	1,161	1,088	988	992	993	1,030	984	1,009	901
female	536	558	521	536	521	560	597	645	618	643	597
total support staff	1,799	1,794	1,682	1,624	1,509	1,552	1,590	1,675	1,602	1,652	1,498
% female	29.8	31.1	31.0	33.0	34.5	36.1	37.5	38.5	38.6	38.9	39.9

Data: DEEWR

Several of the consultations referred to increasing student-to-academic staff (SSR) ratios, and it is quite clear from the data presented here that such ratios have indeed increased since 1996. One submission[33] referred to this ratio increasing from 10:1 in 1988 to more than 20 in 2006. The data presented here supports the latter figure. From Table 2 in 2006 there were 60,752 students enrolled in coursework programs, and from Table 10, approximately 1,691 FTE academic staff to teach them, an apparent ratio of 35.9, assuming that research-only staff do not undertake any teaching. On this basis the ***actual*** sector average teaching SSR is greater than 21, taking into account the ***average load*** factor (approximately 60%) which accounts for students not being in full-time study. This may be an underestimate of the real ratio due to many academics taking relatively low teaching loads as a consequence of their research and administrative commitments. Staffing and other resource issues related to the delivery of coursework programs are discussed further in Chapter 8.

4.4 The growth of engineering research

Research positioning has dominated much of the strategic thinking and development of Australian universities and engineering schools over the past decade. The proposed (but since withdrawn) introduction of the Research Quality Framework to direct research infrastructure funding to the universities significantly increased management oversight of the research activity of academic staff in teaching and research and research-only positions.

Universities require that their engineering schools contribute strongly to their research missions, and in most cases, they have. In several universities, particularly those without medical schools, engineering has been cited as a leading research discipline. At least as much as other disciplines, governments expect university-based engineering research to contribute towards innovation and ultimately provide value to the economy and contribute to the understanding and solution of problems in environmental, security, healthcare and other areas. In practice, much of the engineering research carried out in universities is 'engineering science' research, providing basic understanding and modelling of potentially applicable materials, techniques and system innovations. The research funding systems and universities strongly encourage engineering academics to undertake research in collaboration with industry, and with international partners.

The opportunity to undertake research is the main attractor of many academic staff to universities, and academic appointments and promotion are generally made on the basis of research achievement and potential. Establishing a successful research program as a new member of academic staff is not easy, however, except for the most gifted. Research funding within most Australian universities is limited and external project funding, such as that provided by the Australian Research Council (ARC) is highly competitive. Universities are expected to provide basic research infrastructure; indeed, accepting funding from the ARC grant schemes or participating in a Cooperative Research Centre binds universities into obligations to provide academic staff time and adequate infrastructure support for the research. Few engineering schools can maintain leading-edge research facilities across many engineering disciplines, so most have concentrated their research into a relatively small number of areas.

Most academic groups consulted with in the study have rated Australia's university-based engineering research performance over the past decade relatively highly. The concentration of engineering research into 'centres' and 'institutes' within universities and the formation of larger external, mostly collaborative research organisations, represents a 'professionalising' of managed research, that contrasts with the historic image of isolated 'boffin-academics' researching in their laboratories with one or two doctoral students. Larger research organisations have the advantage of creating critical mass of expertise across disciplines that are more likely to solve the complex problems faced in industry and society at large. Engineering academics have taken the lead in forming multidisciplinary research centres and institutes in areas of sustainability engineering, communications engineering, and new materials, for example. The rapid growth of research-only academic positions (Table 10) referred to earlier, and the 80% growth of doctoral enrolments (Table 2), are consistent with the growth and concentration of research.

Much of the funded research growth in the past decade can be attributed to the Commonwealth's Backing Australia's Ability initiative, announced in 2001. Under this initiative increased funding was provided to establish national research facilities and an institute for Information and Communications Technology innovation and research. The latter has taken form as NICTA[34] with university and state government partners in most Australian states. BAA also increased funding to the ARC for project grant funding, to develop the Federation Fellowship scheme to attract and reward internationally renowned researchers, and to fund a number of Special Research Centres and Centres of Excellence. Basic engineering science research, in particular, has benefited from all these initiatives.

More applied and industry-focussed university research has developed through the Australian Government's CRC program. The goals of this program align with those of engineering, having "*the aim of turning Australia's scientific innovations into successful new products, services and technologies, making our industries more efficient, productive and competitive*" [35]. The program "*emphasises the importance of collaboration between business and researchers to maximise the benefits of research through an enhanced process of utilisation, commercialisation and technology transfer*". The program operates under six sectors: Manufacturing Technology, Information and Communication Technology, Mining and Energy, Agriculture and Rural-based Manufacturing, Environment, and Medical Science and Technology, with more than a third of the 57 current CRCs having university engineering schools as partners. A feature of most of these CRCs is that their research is multidisciplinary.

University research (including that in the CRCs and other Centres mentioned) is different from that carried out in research organisations such as the Defence Science and Technology Organisation (DSTO) and CSIRO, by having the explicit responsibility to develop graduates' research capabilities, first as undergraduates in their senior years, and as postgraduates, especially as research masters and doctoral candidates. The CRCs and many universities have included professional development programs on commercialisation and project management in their doctoral training to equip these graduates with skills for professional employment beyond the research laboratory and academia. Thus, research candidature in CRCs and other industry-linked centres tends to reduce the likelihood of graduates pursuing subsequent academic careers. Strengthening industry through research capability is highly desirable, but having relatively low numbers of research candidates in engineering, adds further potential strain to the engineering academic system, as discussed further in Chapter 8.

Regarding research student numbers, all of the academic consultations made the point that Australia has fewer B.Eng. graduates progressing to research degrees than is desirable or comparable with international institutions. Comparing the number of domestic Bachelors graduates in any year (Table 5) to the number of commencing Masters research degree enrolments (Table 3) in the subsequent year indicates a recent system-wide domestic graduate-to-research progression rate of around 5 – 7%. This figure is highly tentative, and assumes that initial research candidature is at Masters level, which may not be the case across the system. Looking at total research degree enrolments, the figure of 5,413 in 2006 (Table 2) is small for a potential supervision complement of 1,649 teaching and research academics (let alone some of the research-only staff), many of whom would be supervising five or more research students at any time. Having more research degree students of adequate quality would undoubtedly strengthen Australia's engineering research.

Most engineering schools seek to operate with strong connections between teaching and research (promoted as the 'teaching-research nexus'), with the conviction that knowledge from contemporary engineering research has intrinsic value in the later stages of the undergraduate curriculum. Final year projects are often linked to staff members' research activities, and joint (student and supervisor) publication of B.Eng. thesis work is not uncommon.

Emerging Issues

The vitality of many engineering schools comes from their active research, and the academic leaders of such schools are very concerned about the difficulties in attracting and retaining research capable graduate students and research active staff. The tendency for engineering research to grow in centres and institutes that operate separately from the engineering schools responsible for the undergraduate and to some extent postgraduate teaching programs weakens the teaching-research nexus and may place excessive teaching loads on some academics. Some of the academic consultations raised this issue as also reflecting institutional downgrading of teaching. A parallel industry view was expressed as scepticism and concern with an apparent over-emphasis on research in the engineering schools.

Some of the specific criticism in industry consultations was that the research being undertaken is 'blue sky', and not highly relevant to Australian industry. This is discussed further in Chapter 9. More common, and this was also expressed by students, was the criticism that academics were more focussed on their research than their teaching, at the expense of the latter and their willingness to engage with students' learning. Measures to improve the quality of teaching through engineering education research are discussed further in Chapters 7 and 8.

4.5 Undergraduate programs: more diversity than uniformity

Australia's engineering schools range widely in size and mission, befitting their histories and locations. As discussed earlier, B.Eng. programs are structured in several different forms. Nevertheless, all aim to provide accredited programs as their principal product: in this one important sense there is valued uniformity. There are similarities too, in the missions and profiles of the engineering schools in the major university groupings: the G8 group having a strong research focus which influences their approach to education, and the ATN a strong focus on industry linkages. Universities in non-metropolitan cities have extremely close and highly valued links with their communities. Between and amongst these groups are wide variations between the educational approaches taken by their engineering schools. Some for example, may operate their programs in industry-based learning (IBL) format; others may operate substantially through distance education.

Current accredited program data from Engineers Australia reveals that the 32 institutions covered in this study offer single engineering degrees with well over a hundred different degree titles. Almost all offer dual degree patterns. Appendix 8 charts the discipline range covered by each institution, and classifications of size and international engagement based on 2006 total student numbers. The data also shows that a subset of the schools have accredited 3-year Bachelors degrees. Many of these (not shown) are no longer enrolling new students. Even without considering their postgraduate coursework and research profiles, Australia's engineering schools are highly diverse.

A further area of diversity across and within engineering programs is their wide range of entry scores of their commencing students. The cut-off rank (Table 9) is normally well below the median value, and every school and program is likely to have students with very high UAI ranks. Consequently engineering classes in most schools include students of wide academic ability and experience.

Emerging Issues:

A widely acknowledged merit of the revised accreditation system is that its focus on broad graduate attributes has encouraged the engineering schools to devise innovative curriculum and pedagogy to meet their particular missions. This may challenge some academics moving from traditional educational environments. A further challenge is to ensure that the accreditation process has the capabilities to respond to evolving educational missions, whilst maintaining internationally agreed standards on graduate outcomes.

Some of the focus group consultations, particularly in the largest cities, raised the issue of this apparent diversity on the ability of engineering to project itself as a high status area. The proponents of these concerns hold that having fewer engineering schools in total would raise the standing – and hence the attractiveness of engineering – to more able students, and intensify the nation's research endeavours, since the retained schools would be in the capital cities. A similar discussion had been held in 1995-96 for the *Changing the Culture* review, and some would hold that the arguments put there for a smaller number of larger engineering schools still hold true. The present study has found, however, that operating engineering schools only in the capital cities would significantly diminish the nation's engineering capacity.

The consultations and data undertaken in this study, particularly in regional cities and at newer universities, revealed how important their engineering schools are to their communities. Many high UAI students prefer to study in the regions and there are significant research challenges and opportunities for centres of excellence that would not occur if Australia's development was constrained to the cities. In general, the non-metropolitan engineering schools have strong support from specific regional industries and employers. Employers commented that much regional engineering work, particularly in infrastructure research and maintenance, and in operations in specific manufacturing and process industries, has characteristics and is conducted in locations that graduates from metropolitan universities do not seek. Non-metropolitan communities strongly desire students from their regions to have the opportunity to study and then practice in engineering, both in their regions and beyond. The general problem for regional engineering schools is to attract sufficient students (from their region or elsewhere) to develop and maintain adequate resources to ensure program delivery of adequate quality, and to graduate sufficient engineers to contribute to their regions.

Successful strategies to achieve this have included offering engineering at multiple levels (associate degree, B.Tech. and B.Eng.), and in articulated 3+2 forms, with the accredited professional engineering qualification being a masters degree, as at the University of Southern Queensland and the University of Ballarat. There, and at other universities, the provision of entry into 2-year and 3-year program offerings and articulation opportunities based on academic merit, increases the numbers of engineering graduates entering the workforce. At the focus group consultations, several employers reported good levels of satisfaction with the skills level of graduates of 3-year bachelors and support for newly instituted associate degree programs. Other engineering schools, both regional and metropolitan, might benefit from emulating the initiatives taken by these universities, especially where skills demand and student supply have matching characteristics.

Clearly, and as discussed earlier, members of both the industry and academic communities have considerable ambivalence towards three-year engineering (B.Tech.) degrees and the engineering technologist occupation. Associate Degrees are also a new concept to most engineering schools. The idea of introducing new 3-year degree programs and associate degrees would be viewed by many engineering schools as a considerable risk, given the current lack of student demand for these awards in recent years. Furthermore, these universities might regard such a move as a downgrading of the status of their engineering operation. Nevertheless, developing successful 2- and 3-year engineering programs could fulfil several broad community expectations, including higher graduation rates and strong employer satisfaction. Recommendation 2 of this report proposes a number of actions related to research and action on these ideas.

A further cause of concern raised in many consultations is the attrition rate of students from engineering schools. Industry contributors generally applauded engineering schools' desire to maintain high standards, while also expressing concern that, on average, only slightly more than half of the commencing engineering students graduate. Much lower graduation rates are likely, however, where a program has lower that average course success and retention rates. For example, if these are 0.66 and 0.77 respectively, the average graduation success rate would appear to be in range 20 - 35%. On these figures, a commencing cohort of say 60 students could lead to final year classes with fewer than 15 students, especially in elective options. Needless to say, these students will be the most able ones in the class and probably attained much higher UAI ranks than the published cut-off. Engineering schools with that pattern of graduation success would be somewhat vulnerable to resource constraints. Further examination of engineering school data indicates correlation between low course success and retention rates and low published entry cut-off ranks.

The question of major importance is whether the students who enter B.Eng. programs with a very low UAI (say less than 70), and who fail to progress in their programs might have the capability to graduate from 3-year bachelors or associate degree programs and succeed in entering the profession at engineering technologist or engineering officer levels. If that were the case, they, industry, and their engineering schools would all benefit. Naturally, such students would need supplementary pathways and nurturing beyond that associated with standard B.Eng programs.

4.6 The growth of international student enrolments and postgraduate programs

International student enrolments

As reported earlier (see Tables 2 and 3), most of the last decade's enrolment growth in Australia's engineering schools has been through international students. Most of these are students are enrolled in undergraduate coursework programs in Australia. The international enrolment numbers (as opposed to proportions of the totals) in postgraduate and undergraduate programs are presented explicitly in Table 11.

Table 11 International total and commencing enrolments, and graduating student numbers in undergraduate and coursework programs, 1996 – 2006.

international students	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
total enrolments											
research	803	747	722	705	683	929	1,014	1,142	1,344	1,512	1,692
postgraduate coursework	709	775	804	933	1,300	2,353	3,039	4,592	5,067	5,296	4,768
undergraduate	4,153	4,719	5,007	5,588	6,020	8,099	9,603	11,126	11,789	11,989	12,419
total enrolments	5,665	6,241	6,533	7,226	8,003	11,381	13,656	16,860	18,200	18,797	18,879
% female	14.2	14.3	15.0	16.3	16.6	17.5	17.5	17.0	17.1	17.4	17.7
commencing enrolments											
research	272	271	278	263	288	358	366	415	467	449	539
postgraduate coursework	480	528	556	732	999	1,526	2,002	2,998	2,949	2,874	2,617
undergraduate	1,647	1,785	1,633	2,065	2,254	3,394	3,964	4,354	4,014	4,013	4,150
total commencing enrolments	2,399	2,584	2,467	3,060	3,541	5,278	6,332	7,767	7,430	7,336	7,306
% female	15.5	13.9	15.5	16.9	17.6	16.6	17.0	15.9	16.4	17.5	17.6
graduations											
research	181	202	179	167	165	157	140	154	222	260	
Postgraduate coursework	408	515	533	556	683	1,024	1,221	1,861	2,061	2,494	
undergraduate	731	811	1,018	1,254	1,431	1,676	1,789	2,084	2,290	2,463	
total graduations	1,320	1,528	1,730	1,977	2,279	2,857	3,150	4,099	4,573	5,217	
% female	11.9	13.4	13.4	15.8	16.1	18.6	18.0	17.9	18.3	17.7	

Data source: DEEWR via Engineers Australia

Much of this international enrolment growth can be viewed as a successful response to international education market conditions that were particularly favourable to Australia from the latter half of the 1990s to the early years of this decade. During that period, the international exchange rates made programs priced in $A better value than comparable programs in USA and UK, the dominant international education destinations for international students from the Asian region. Australia also gained favour over USA and UK on perceived personal security grounds.

Most Australian universities professionalised and focussed their international student recruitment activities during this period. In recent years the strengthening international value of the $A has reduced Australia's price-competitiveness in higher education, with corresponding reductions in the rate of growth of the international education market.

Against the background of fairly static domestic enrolments for most engineering programs (and non-indexed funding for their support), many engineering schools focussed on increasing their international student enrolments into established programs and into newly created ones to meet new demands. A small number of universities also established engineering programs outside Australia, the largest of which is Monash University's campus in Malaysia. In contrast to this campus-based model, most offshore engineering programs are operated in partnership with education providers based in the host country. Since the focus of the present report is primarily on the provision of graduates for Australian industry, this study has not specifically addressed the off-shore activities of engineering schools, except to note that this adds a further level of complexity and workload of staff in engineering schools.

Having an average cohort of about 30% international students in the bachelors engineering programs on Australian campuses is widely regarded as a comfortable proportion, providing good opportunities for Australian students to gain intercultural understandings, and for the international students to gain useful understanding of Australian education and culture. The data in Table 8 show that international undergraduate students have similar success and retention rates as their domestic classmates.

The data in Table 2 and 3 show that international students dominate many of Australia's postgraduate coursework programs, having seen a sixfold increase in numbers of 1996 to 2006. Many of these students have the expectation that their programs will assist their immigration into Australia and ultimate employment in the engineering profession. The Commonwealth government's recognition of the skills shortages in engineering resulted in some relaxation of visa requirements, and their focus on regional universities had further impact on the distribution of students across the higher education sector for engineering. The market requirements of content and focus of postgraduate engineering programs have gone beyond the traditional model of 'advanced technical studies' for postgraduate coursework programs, as discussed below.

Postgraduate coursework programs in engineering

Bachelors degree programs in engineering have the clear primary objective to provide entry-level accredited education to professional engineering and engineering technologist qualifications. Postgraduate coursework programs, in contrast, can be devised to meet a number of different educational objectives, and thereby satisfy a range of prospective students' needs. The landscape of postgraduate program provision in engineering has diversified markedly over the decade, as Australian engineering schools have responded to a number of demands and markets with each new postgraduate coursework program being scrutinised and approved by its own university's academic processes. The baseline policy of most Australian universities is to award masters degrees after four semesters of full-time study for graduates of 3-year Bachelors degrees, consistent with the Australian Qualifications Framework.

From systems and quality assurance perspectives, ACED has been concerned for several years that the diversification and growth of engineering masters has been outside any clearly defined national, or internationally understood framework for such awards. In 2005, Simmons provided ACED with a survey (ref 20) of Australian engineering coursework masters programs to assist the council to devise a methodology for endorsing those programs that met defined standards of content and purpose. The survey reported that Australia is not alone in having a wide diversity of postgraduate programs in engineering and ambiguities of nomenclature. More than a decade ago, the UK reported similar issues[36] across its higher education system, and subsequent recommendations were made for relevant quality assurance.

The ACED survey collected program information from university web-sites (as prospective students might) and identified 117 named engineering masters by coursework programs, varying in duration from 2 to 4 academic semesters equivalent full-time coursework. Many of these programs are 'nested' with graduate certificates and graduate diploma awards. The programs are provided by a range of delivery methods, including by distance-education, and some are operated in collaboration with internationally-based universities. Most of the programs incorporate project work, in some case up to 50% of the total program time. Many programs also allow for students to take undergraduate courses, as part of their masters program. Simmons reported that the stated program aims fell into six categories, summarised here under three headings, as:

- discipline specialisation, focussing on in-depth technical material, and possibly oriented towards postgraduate research studies, with normal entry qualification being a four-year engineering degree;
- conversion programs, either for engineering graduates to change to another branch of engineering or for graduates without an accredited professional engineering degree to gain a qualification that would be recognised by Engineers Australia at professional engineering entry level;
- continuing professional education, including broad-based professional training for engineers and engineering managers focussed on career advancement, and specifically to develop management and leadership skills for engineering work.

ACED's primary concerns have been that all of these awards have the masters title, but programs in the second group may be closer in terms of outcomes to bachelors degrees than be at the advanced level normally associated with the masters title. ACED has proposed working with Engineers Australia to develop a framework for recognising these programs.

Domestic enrolments in postgraduate coursework programs increased only by about 25% over 1996 – 2006, compared with the sixfold increase in international enrolments. The consultations in this study explored this domestic demand from both industry and academic perspectives, finding that:

- there is small demand for postgraduate level specialist or conversion award programs, confirming Simmons' findings;
- industry expects most technical specialist skills updating needs to be met by short courses, by in-house company specialists, or by private providers, or less commonly, university-based providers, including CRCs;
- many engineering graduates will aspire to enrol in MBA programs to develop their careers, often supported by their company.

Having strong specialist postgraduate coursework program is a measure of higher education quality in some countries. Australia's engineering education enterprise is generally weak in this regard. Having an adequate number of students at a single location to warrant developing specialised postgraduate award programs with the expectation that it will run for several years is a genuine challenge. Nevertheless there is one engineering-based industry sector – defence – in which such programs have been developed for their employees.

Under the Skilling Australia's Defence Industry[37] (SADI) initiative the Commonwealth government is supporting defence industry companies, including small and medium sized enterprises (SME's) to partner together and with universities to have specific postgraduate award programs delivered to employees usually on-site. A notable feature of one such program, the M.Eng.(Military Systems Integration)[38] at the University of

South Australia, is that it caters for staff of three potentially competitive defence companies.

A second approach that exploits the expertise at several universities is the Defence Science & Technology Organisation's (DSTO) postgraduate Continuing Education Initiative (CEI) is described in Box 1. This is an example of quite complex industry-university and private sector cooperation, involving coordination of programs and courseware from several Australian universities.

These two examples illustrate solutions to ensuring that the postgraduate awards have sufficient students in the classroom to make development and delivery of the course material cost-effective, and that the programs are developed and delivered by the best available expertise.

Box 1: The DSTO Continuing Education Initiative

The Continuing Education Initiative (CEI) is a corporate program aimed at maintaining and enhancing DSTO's science and technology base and research capability. The CEI commenced in 2002 as a program of part-time postgraduate study in a selected range of scientific and technological disciplines that lead to the award of a Graduate Certificate, Graduate Diploma or Masters Degree, or staff may opt for individual courses. Several hundred employees have undertaken courses within the program.

DSTO is committed to ensuring that staff from all sites are able to participate in the CEI. Therefore many courses are available online or on-site.

The selection and, where appropriate, the development of specialist study streams, leading to Masters programs and individual courses under the CEI, is key to the CEI's ability to best meet DSTO's specific needs. DSTO has identified five universities to cover its seven program streams, including defence technologies, ICT, signal & information processing, systems engineering, operations research, materials and structures, and human-factors.

The program is managed and administered under contract to DSTO independently of the individual program providers, by SACITT (a consortium of the three public South Australian universities) and AITEC Pty. Ltd.

Source material: www.aitec.edu.au/cei/

Emerging Issues

There is considerable concern amongst the heads of engineering schools that international demand for engineering studies in Australia is variable and perhaps softening, due to a higher $A exchange rate than a decade ago, and the development of more engineering schools in many counties in Asia. Offshore operations in engineering education do not generally offer high financial returns, and certainly increase the workload complexity for the host engineering school. Future directions are uncertain.

The lack of postgraduate program accreditation, referred to earlier, other than to the special cases referred to in section 2.3 (b) and (d), was raised by all engineering schools. Engineers Australia currently limits accreditation to those programs provided by Australian educational institutions that are designed to deliver graduates ready to commence practice at one of the three occupational levels. Graduates who have an engineering qualification at the bachelor level that is not recognised by Engineers Australia, and subsequently complete an Australian master's degree can submit their individual case for assessment against the Engineers Australia Stage 1 Competency Standard. Many international students are surprised, however, by the absence of ***program accreditation*** at the professional engineering level for either of the first two groups of masters programs described above. If known in advance, this fact might have been a disincentive for application and enrolment into their postgraduate program. This poses a threat to many engineering schools, and an opportunity for others.

In recognition of these circumstances, Engineers Australia has declared its commitment to examining program accreditation of masters awards. The major difficulty is that program accreditation of professional engineering qualifications requires the graduate attributes to be demonstrated through the curriculum to an equivalent level as those developed in four-year B.Eng. degrees. The typical stand-alone three-semester masters' program tends to focus on technical content, rather than these broader attributes. It is not beyond possibility, however, that specific postgraduate programs could be devised to meet some or all of these accreditation requirements, when combined with adequately defined entry pathways. Having such programs could assist Australia to meet its demand for engineering skills through migration linked to education and qualifications upgrading that ideally would also include embedded experience in industry, with potential benefits for all stakeholders. These ideas are developed as options in Recommendation 6.

A number of the consultations raised the possibility of meeting increased need for expertise in engineering project management through new masters programs, complementing the more general management skills development in most MBA programs. These should have high demand. Many would also see value in developing engineering and technological management themes within MBA programs that would also foster valuable collaborations between engineering and business schools.

Several academic groups expressed the concern that the general lack of specialist advanced programs in engineering signals a fundamental weakness of Australian engineering industry. The perception that Australian engineering is not seen to be driven by advanced technological innovation is discussed further in Chapter 9.

5 Employer demand for engineering graduates

5.1 The context of demand for engineering graduates

This study has been conducted in a period of high demand for engineering skills at all levels, from trade to graduate. Unsurprisingly, most engineering students who participated in the consultations were optimistic about their future employment and career prospects. Some, however, were aware that in some field, the demand for ***experienced*** engineers is higher than that for graduates. Most students, however, reported headhunting by industry from early years of their studies, good industry-experience opportunities, and the increased availability of scholarships and other financial inducements. Students reported that many companies were offering attractive graduate development programs.

Annual graduate surveys (refs 22, 23) confirm that graduate engineers attract good remuneration, having being ranked 4 on median starting salary after dentistry, optometry and medicine for the last 5 years. The 2007 graduate engineer median starting salary of $50,000 was 25% higher than the corresponding figure for business and economics graduates. All engineering discipline areas reported high full-time graduate employment rates (86.2% to 98.7%), compared with the higher education mean of 84.5%.

Engineers Australia has recently estimated[39] a shortfall of at least 20,000 professional engineers (against a total of about 150,000) to meet current demand in Australia, and also noted that graduating fewer than 6,000 domestic bachelors engineers per year (as may be computed from Table 5) is inadequate. This large shortfall of engineers and engineering technologists is, of course, not evenly distributed amongst industry sectors, engineering disciplines nor amongst the levels of engineering expertise most urgently required. Labour demand studies based on Australian Bureau of Statistics (ABS) occupational classifications are also problematic for engineers because this classification scheme confines 'engineering' to entirely 'technical' occupations. Reference 3 explains the classification problem in detail. In summary, statistical work based on ABS classifications may exaggerate the apparent loss of many graduate engineers to 'management', and also underestimate the size of the shortage of graduate engineers. The frequently made ***negative*** observation that only half of the graduate engineering cohort are working as engineers five years after graduation needs further analysis and careful interpretation in relation to the value of engineering degrees to the community at large.

The following paragraphs elaborate on the skills shortage issues from the perspectives of two industry sectors and of one region, as raised in the consultation processes of this study. The chapter concludes with a commentary on the views on increasing the supply of engineering technologists into the graduate engineering population, and on how engineering education might further support migrant engineers, who will continue to make very important contributions to Australia's engineering workforce. The critical shortages of engineers undertaking higher degree research and of engineering academics were noted in many of the consultations, and are discussed further in Chapter 8.

5.2 Skills shortages in identified sectors

The mineral industry sector

A 2006 national study[40] on the future labour requirements for the major resource sectors of the minerals industry projected a need for 70,000 more workers by 2015. The data shown in Table 12, by occupational classification and by mineral resource, are instructive. The study used a six-category classification, of which the top two, managers and professionals would normally have graduate qualifications, and the third, technicians, would be at the engineering officer level. The study report does not provide information on the disciplines required, but the technological nature of the industry would indicate that a significant proportion of the managers and professionals would be degree qualified engineers, and most of the technicians would also be trained in engineering fields.

Table 12 Projections of additional labour needed in the major sectors of the mineral resources industry

occupational classification	mineral resource									total	% of total
	coal	iron ore	gold	bauxite	copper	nickel	zinc	lead	uran'm		
managers	1,448	573	124	42	487	206	34	14	2	2,930	4.2%
professionals	1,232	2048	668	1,757	992	520	289	120	25	7,651	10.9%
technicians	410	1288	159	1,353	469	272	137	55	10	4,153	5.9%
trade	4,107	3073	4,560	1,118	4,361	6,845	1,689	680	550	26 983	38.5%
semi-skilled	7,872	5887	765	3,424	3,201	786	86	35	3	22,059	31.4%
labourers and related	716	573	786	3,019	863	213	103	41	64	6,378	9.1%
additional total	15,785	13,442	7,062	10,713	10,373	8,842	2,338	945	654	70,154	100%
2005 baseline	28,904	15,131	18,335	10,244	639	7,211	3,800	1,321	639	86,224	
growth to 2015	35.3%	47.0%	27.8%	51.1%	94.2%	55.1%	38.1%	41.7%	50.6%	44.9%	

Data: compiled from data in Reference 40

The annual production of bachelors' degree engineering graduates, as shown in Table 6, is clearly insufficient to meet the projected additional needs of the top two occupational levels in the minerals sector, even if demand in other sectors remained static. The extreme need for more trades and semi-skilled workers is also clear. One caveat, however, is that these projections do not assume major labour productivity gains over the period. Since there are also very large investments in engineering research in the minerals industry, and in a range of university-linked research centres, including CRCs in the area, it would be reasonable to expect engineering research and innovation to contribute to increases in labour productivity and thereby lessen some of the lower skilled labour demands.

Graduate shortages in the minerals sector were raised in many of the consultations, noting that the minerals sector requires graduate civil, environmental, mechanical and electrical engineers as well as those with mining engineering and minerals processing qualifications. The decline in the production of graduates in the latter disciplines that took place in the 1990s, due partly to the cyclical and then unfashionable nature of the industry, are being reversed by industry-led initiatives, described in section 10.2. Many engineering students, particularly in Western Australia and Queensland, reported on the industry's active recruitment during early stages of their programs, and their very good remuneration prospects on graduation. Some students also talked of their school class-mates declining university places to work in the industry, a trend reported in the press in early 2008[41].

Other industry sectors expressing skills shortages

In the course of the present study, several other industry sectors reported current and prospective shortages of engineering graduates. The most commonly mentioned industry sectors discussed were electrical power and defence. The defence area's concern with shortages of ***experienced systems engineers*** rather than first degree graduates, has led initiatives in postgraduate up-skilling, as described earlier. Box 13 in Chapter 10 describes an initiative in the power industry to meet future graduate demand, citing the need for 700 – 1,000 additional graduates over the next 5 years.

Other areas of skills-shortage mentioned in focus groups were civil (construction), water, transport, railway engineering, fire safety and environment, and project management. The lack of availability of well-trained software engineers was also described as critical. The post 'dot-com' decline in engineering enrolments in all program areas associated with information and communications technology was regarded as potentially critical across many industry sectors, as engineered products, systems and services become increasingly dependent on embedded and networked software. One consultation referred to the lack of capability in nuclear engineering.

Students at one university commented that there were indeed plenty of jobs in software engineering. In general, however, the lack of ***large Australian companies*** in the electrical and electronics industry was stated to be a disadvantage for graduates in those disciplines.

5.3 A study of engineering skills shortages in the Hunter region

State and regional priorities in engineering were evident at the consultations held outside the capital cities. One example of a regional study on engineering skills demand was discussed at the consultation at the University of Newcastle. Concerned with engineering skills shortages in the Hunter region, the Engineers Australia Newcastle Division commissioned a demand profiling study in early 2007[42]. From the executive summary, the focus group based study identified several issues that relate to other parts of this report:

- *the urgent need for workers with engineering and technical skills to clear the current backlog of work, and undertake future programs*
- *that 5 – 10 year experienced engineers are in particularly high demand*
- *that Generation Y graduates are difficult to recruit, as they have values that are inconsistent with traditional workplaces*
- *employees are increasingly attracted to contract work, long-term commitment has become less valued*
- *there is declining number of women applying for engineering positions*
- *the ageing workforce causes loss of capabilities, including mentoring, and in the VET (TAFE) sector there is inability to recruit professionals into teaching*
- *geographical restrictions are less important than they were, with engineers working remotely and using new technologies*

The study estimated the current shortage of engineers to be about 20% in most discipline areas, the highest being in civil - geotechnical (27%), and lowest in electrical (14%). A shortage of more than 120 general civil engineers was identified. In relation to functional role, the study identified clear shortages of engineering technologists and engineering officers, specifically as "*skilled CAD experts and skilled draftsmen*". There was no apparent shortage of tradespeople. Shortages of professional engineers were ranked slightly higher than those of technologists.

This study, and there may be others, appear to be very useful in assisting the profession and engineering education to focus on activities that will best redress the shortages of engineering graduates.

5.4 Demand across the engineering occupations, and responses from engineering schools

The focus group consultations uncovered considerable disparity of view on the relative demand and importance of the different levels of engineering qualification, that is for those qualified at the entry level as professional engineers, engineering technologists and engineering officers. While some industry contributors were highly satisfied by graduates of 3-year programs, others were dismissive of the concept of 3-year qualified 'engineers'. Nevertheless, in further discussion most of the industry participants and professional groups recognised a need for workers at levels between VET trained and professional graduate. This was expressed in the Hunter study as needs for skilled CAD experts and draftspersons, and by others as experienced supervisors and experienced technicians. These were identified as people who in the past had VET qualifications, experience and possibly additional qualifications. The report also stated that "*professional engineers find these roles unfulfilling*", an observation that needs careful interpretation with respect to creating harmonious engineering teams.

Others referred to 3-year qualified roles for designers, in field operations, as specialists in municipal water and drainage, and also as specialist project managers. The general industry view was that the lack of occupational definition around the 3-year engineering technologist was a critical barrier to having the role more accepted within industry. One engineer (who had held high office in Engineers Australia) was emphatic that Engineers Australia has "*not got this right*", and suggested that only about 10 – 15% of the engineering workforce should be working as professional engineering level, doing the conceptual thinking and, and supervising a team of 8 – 10 engineering technologists and engineering officers. He observed that "*many fifty-plus engineers are doing technologists work.*"

The academic groups were much less enthusiastic, and even strongly opposed to their schools responding to the 3-year qualification concept, unless they had built such a program successfully to satisfy local needs, such as at the University of Ballarat, University of Southern Queensland, and Central Queensland University. The functional areas identified as useful by industry in the preceding paragraphs do not resonate well with most research-oriented engineering schools. A common view was to leave technologists and technicians to the VET sector. This view exhibits a lack of understanding of the graduate level required of engineering technologists, and the opportunities that exist to offer programs at Associate Degree level. There would, however, be merit in working with some VET providers in developing university programs for these awards, as is happening in some institutions.

Much of the negativity within universities and engineering schools towards providing qualifications other than at professional engineering level is that such qualifications are viewed by prospective students as 'second class', and are thus unmarketable. Actions that may contribute to deeper understanding and that may in future satisfy industry demand for engineering technologists and officers, and attract more students are proposed in Recommendation 2.

On one hand it is clear that the engineering education system cannot be as strongly coupled to industry sector demand as some in industry and government would desire, because of the cyclical nature of much of Australian industry (see section 10.2). On the other hand, the consultations revealed the need for urgent actions to be taken to enable the Australian education sector to strengthen graduate numbers to help alleviate the acute shortages of qualified engineering practitioners projected for the near future. Action imperatives discussed included undergraduate programs that attract and graduate more students particularly from non-traditional backgrounds, and postgraduate programs that support qualified engineers and others to enter or return to the profession (see Recommendation 6).

Most universities will attempt to devise and offer sets of engineering programs that both attract sufficient students to be viable and satisfy known industry demand. While there is enormous diversity amongst bachelors engineering degree programs, as described in this report, and many ways that students can combine engineering with other areas of study programs in dual degrees, the current tendency in the sector is to make undergraduate engineering programs more generic, and provide less specialisation. Many industry participants expressed strong support for this, in terms of "*concentrating on the fundamentals*". There is broad agreement on the fundamental attributes that graduate engineers should possess, but each engineering area, as represented by the Engineers Australia's Colleges, for example, has strong views on what is fundamental to its particular area, and what constitutes its evolving areas of specialisation. There will undoubtedly continue to be debate on these matters, as schools develop and refine their curriculum, and the industry sector refine and articulate their needs.

Many engineering schools would view increased demand for postgraduate study in engineering specialisations as a sign of industrial health, ensuring that engineering enterprises are being operated with leading edge technologies and processes. Many engineering schools would then partner with each other, and with industry, to develop postgraduate level specialisations to support industry needs, for domestic engineering graduates, and to support the transition of some of the migrant engineers into Australian engineering enterprises. Some of these issues are addressed later in the report.

6 Engineering students and student demand

6.1 Introduction: the domestic student demand trends

The data provided in Chapter 4 show that domestic student commencements in undergraduate engineering programs increased marginally in recent years to 2006, but also that these are a declining percentage of total undergraduate enrolments. The number of commencements is primarily dependent on two factors: the number of qualified applicants and the proportion of these who are motivated towards engineering. Whether motivation or qualification is the more important is a moot point. However, increasing the number of university places assigned by funding does not directly increase this pool. Many engineering schools have the capacity and desire to take higher numbers of adequately qualified domestic students. Many have experience of attracting Australia's most able school leavers.

Data for the current year, 2008, are however, providing some positive indications. Average engineering cut-offs have been reported[43] in the press as increasing by about 4 UAI points compared with 2005, against an average fall of approximately 4 points across all disciplines examined. Interest in civil engineering programs is being reported by individual universities to be particularly strong, against continuing softening in the demand for electronics, telecommunications and computer engineering. These trends appear to be continuing into 2009.

In any event, prospective domestic graduating numbers may not satisfy the continuing overall demand for engineering graduates: in the short and medium terms this will continue to be satisfied by recruitment of international graduates either directly, or via migrant engineer programs, some linked to postgraduate study as described earlier, and by recruitment of international students into undergraduate programs. Nevertheless, the Australian engineering profession expects to be supplied primarily by domestic graduates and appears is generally keen to support measures to increase enrolments, as discussed in Chapter 10.

The most common pathway to a professional engineering qualification is to enter a Bachelor of Engineering program directly from secondary schooling. Engineering has few transferees from other tertiary programs, and most engineering schools have relatively few mature-age entrants with VET qualifications. The key academic hurdle is mathematics, being invariably the stated pre-requisite area of study for commencing engineering studies at all levels. The second limiting factor is the apparent attractiveness of engineering to only a small proportion of women. As noted earlier the participation rate of women has declined since 2000 – 2001. The contexts of these two factors are discussed next.

6.2 Mathematics in schools: reality and perception

Australia's higher education engineering programs have been built on the assumption that students will have studied secondary school mathematics and science at high levels. This assumption is now being tested across the system in various ways.

Barrington[44], and later, Barrington and Brown[45] have reported the declining participation rates in advanced and intermediate mathematics in senior school certificate mathematics subjects across Australia. In summary, about 80% of all candidates working towards their senior school certificates include some mathematics, but each year the proportion taking the higher levels declines. Between 1995 and 2006 the proportion taking advanced level fell from 14.1% to 10.4%, and for those taking intermediate mathematics as their highest level, the fall was from 27.2% to 21.3%.

Nationwide in 2006, this ~ 30% population share corresponds to about 60,000 students. These students will be able to choose widely amongst tertiary programs, including the ~ 10,000 commencing engineering undergraduate places currently taken up each year. Barrington and Brown legitimately pose the question "*will we have enough sufficiently prepared students for engineering places in future years?*" They and others also observe that many engineering academics "*want all the mathematics up front*" so that they can use it in developing analysis and synthesis techniques using sophisticated engineering models. Consequently engineering schools strongly prefer students who have studied advanced level school mathematics and many students in this category develop their mathematics and science further. Unless strong measures are taken within the school education system, top-achievers with high levels of mathematics may become a decreasing proportion of the commencing engineering student cohort, with long term negative impact on Australia's engineering capacity in research, innovation and industry leadership.

For both engineering schools and secondary schools this decline of student participation in advanced mathematics in secondary schools is highly problematic. To fill the available engineering places from a pool that contains a declining number of 'fully mathematically qualified' school leavers, many engineering schools have reduced their entry requirements or expectation of assumed knowledge for entry to B.Eng. programs to the intermediate level. The engineering curriculum has to be adapted accordingly, by including the 'school level' mathematics content, and thereby compromises the depth and breadth of the whole program and graduate outcomes. To secondary schools – teachers and students – the relaxation of the tertiary requirements in mathematics signals that is it is less important in engineering than it was. There is strong evidence to support the view that reducing mathematics entry requirements for university programmes leads to the reduction of mathematics provision in the schools sector.

Proficiency in mathematics and statistics are essential and fundamental components of every engineering program, as discussed further in the next chapter. Proficiency in school mathematics has also been reported[46] as a good predictor of later success in engineering courses that are not 'fully mathematical'. Such messages, stated unequivocally within the engineering community and school education sector in Australia, could help to reverse the current school mathematics participation trends, and increase the pool of prospective engineering students.

Nevertheless, some contributors to the study have questioned whether demonstrated high level achievement in mathematics, as opposed to aptitude for quantitative modelling and logic, should be the dominant formal requirement for engineering study. They assert that the necessary mathematics for understanding scientific models and software tools for engineering can be built from a lower base, and developed alongside and within engineering content. Entry levels of mathematics for B.Tech, and associate degrees would also be at a lower level than those required for B.Eng. programs.

6.3 Women in Engineering: continuing challenges for the education system and workplaces

Increasing the diversity of the engineering student population was a goal of the *Changing the Culture* review. A strong emphasis of that review was on recruiting more women into engineering programs that would have changed to be intrinsically more attractive to them. Many university-based *Women in Engineering* (WiE) programs were already funded and in operation to support these goals. Over the decade, the number of such programs declined. An exception is the one at the University of Technology Sydney that celebrated 25 years of operation in 2006[47]. The proportion of women commencing undergraduate engineering programs peaked in 2000 - 2001 and has since fallen to below 15%, with the domestic student component of that around 13.4%. Since women form the majority of all tertiary students (54.7% in 2006) their continuing gross under-representation in engineering is critical.

Understanding and eliminating the factors that have led to the decline in female participation in engineering studies, and in professional practice is critical. Engineering has been the slowest of all professional areas to shed its male image. Engineers Australia designated 2007 the *Year of Women in Engineering* and marked the year with many initiatives and activities, culminating in publication of profiles of the accomplishments of twelve women who have pursued their engineering careers with dedication and passion, under the title *Stories of Inspiration*[48]. In their submission to this study, Engineers Australia's *National Women in Engineering Committee* identified relaxation of pre-requisite subjects and the good employment market for engineers as possible contributors to recent slight increases in demand for engineering by women. They have also called for action, including redeveloping well-resourced dedicated WiE programs with commitment from engineering academic leaders, as proposed in Recommendation 6 of this report. This committee has also identified a number of curriculum changes in the direction of inclusivity that are discussed in section 7.3.

Part of the low attractiveness of engineering programs to most women also stems from their perceptions of engineering work and career pathways. They may be apprehensive of engineering workplaces in which they perceive there to be harassment, discrimination and bullying. Regrettably, these are also the reality. The recent Career Review of Engineering Women[49] conducted in Australia found 42.3% of women engineers reported that they had experienced discrimination, 22.0% that they had been sexually harassed, and 28% that they had experienced bullying. (Nineteen percent of men also reported that they had experienced bullying.) Surveys continue to show that female engineers earn less than male engineers, are under-represented in positions with high responsibility levels, and on average have fewer children than either male engineers or women in other jobs[50]. These results demonstrate a need for engineering educators to educate ***all*** engineering students about the social and political dimensions of engineering workplaces, in order to prepare their graduates for work, and to improve the culture of engineering workplaces of the future.

Recommendation 6 this report proposes a number of specific actions that are intended to increase the participation of women to enter engineering education and to assist their return into the profession. The general issues of promoting engineering more effectively in the community and within schools are developed in section 6.5 and Chapter 9, with corresponding actions under Recommendation 1.

6.4 Characteristics of current engineering students and early career graduates

In the course of this study more than 250 students and early career graduates have provided opinions on their careers prospects, their curriculum and most importantly for the present discussion, on their reasons for studying engineering. One comment covered several of all these areas:

> "*Young people who are thinking about what to study at university have not really been taught what the bachelor of engineering qualification is about. It is not just something to do if you want to design infrastructure. It is a broad-based design degree which teaches critical thinking, time management, and most importantly, how to learn. With these skills you can go anywhere, and do almost anything. Reflecting on my program … [engineering] has been the best training imaginable I think. Difficult, but it has transformed the way I think and approach problem-solving and learning. The best 5 year investment I could have made in my future.*"
>
> Email from a B.Sc. B.Eng. joint degree student from James Cook University, sent after the focus group consultation

Many students spoke of the career opportunities and the prospectively good salaries that engineering offers. Others referred to engineering's creative dimension in terms of developing specific technologies as inventors and entrepreneurs. Several students were inspired by the prospect of work as engineers in providing solutions to global challenges in the provision of sustainable infrastructure, most often referring to energy, water, food, health, transport, safe shelter and security, and to the rising global population. Many talked about moving into management, one student being emphatic that he had taken engineering as a *"good way to get to management"*. Several were anticipating working in the finance and banking sector after graduation. Most students valued their work experience to assist both their engineering learning and career planning. Many students also talked of their high expectations of employers to provide good working conditions and opportunities for professional development. Such students are generally strong advocates for their educational choice, and their prospective careers. Similar findings have been elaborated in a recently completed DEEWR survey of final year engineering students[51].

Most students also spoke of engineering as the *"invisible"* profession that they chose either because of the influence of a family member, or on the recommendation of a school teacher because "they were good at mathematics and science". There is an implication here that these competences are considered sufficient to succeed in engineering and competence in English and humanities is less important, or even irrelevant. There is evidence, however, that the latter skills strongly support success in engineering studies and subsequent careers in engineering. Students' broader understandings and insights on engineering grow during their period of study. The lack of visibility of engineering is discussed further in Chapter 9.

Engineering programs have developed a reputation for having a number of negative characteristics. Many of the students also talked about the main detractor to engineering study being the reputation of having ***high workload over four years*** of study. The workload perception issue is long standing, having been identified in the 1988 Williams Review[52] and the *Changing the Culture* review. Others reported the perception that after all the hard work there would be only a relatively low salary ceiling attainable, compared to business and law. Few students mentioned the HECS debt as a detractor: to explore whether this is the case would need a study of students who have not chosen engineering. Some students reported that the strongly prescribed curriculum is in itself demotivating: having the chance to exercise choice of courses would itself promote more commitment. Further comments by students on the engineering curriculum are provided in the next chapter.

This comment on the lack of curriculum choice may be related to commonly described characteristics of the current school-leaver generation. Born in the decade since 1985, Generation Y is characterised as a group with somewhat paradoxical characteristics in relation to employment, and by inference, education. Australian GenY members are said by business to be "*demanding, impatient and bad at communicating*" [53], but also have "*energy, creativity and charisma*"[54]. Others report that the Gen Y identify with corporate social responsibility, a desire to develop and use diverse skills, teamwork, challenging work, international travel, work-life balance, being well paid, and feeling that they are making a difference.

Many academics expressed to the present study their concerns that typical contemporary students deal less well with mathematics and analysis than their predecessors, and take a more superficial approach to learning. Some academics also referred to increasing incidences of cheating, copying and plagiarism. As a result, on average, academics judged students to achieve less that those of previous generations. As noted above, however, students mostly stated that they were working hard, and that it was necessary to do so to keep up with assignments and laboratory reports.

Even those contributing to this study who questioned the value of such generational labels agreed that contemporary students are generally time-poor, and fit academic study into busy lives that include paid employment and their communication-dense social commitments. All agree that contemporary students are adept in using the internet and multi-media communications; and have the expectation that higher education will embrace these technologies effectively[55] in curriculum delivery and student support. As a group, GenY and its successor 'Millennial Generation', is unlikely to respond well to conventional classroom teaching. Therein lie opportunities for engineering education to use problem-based and active learning educational methods more effectively, as discussed in the next chapter.

The need for prospective students to encounter positive role models from engineering came through strongly in the consultations. When questioned, few students saw engineering academics as role models as engineers: students are looking to industry for them. This is a suitable point in this report, however, to highlight the work of the young engineers who created The Natural Edge Project (TNEP), summarised in Box 2.

TNEP is an exceptional project that demonstrates many positive personal and professional values and outcomes: of volunteering, commitment to strengthening education and research in sustainability, and creating a university-independent and authoritative source of educational materials. Above all it demonstrates that excellent work does not need years of experience. Yet in building these outcomes, most of this team of engineers may not be perceived to be engineers, as their product is not a physical system. The importance of having the ***intellectual outcomes*** of engineering, including courseware and research recognised as engineering as much as physical systems, is vital to the health of the profession.

TNEP is one example of excellent work by a group of young Australian engineering graduates. There are undoubtedly many others making excellent contributions to development and practice of engineering in industry, business and research: several have contributed to this study. School students would benefit from the inspiration that such graduate engineers can provide, and potentially increase student motivation towards engineering. As many academics have asserted it should, engineering would then become a highly sought-after ***generic degree of choice***, much as law, business and commerce have become.

Box 2: The Natural Edge Project

The Natural Edge Project (TNEP) is an independent Sustainability Think-Tank based in Australia. TNEP operates as a not-for-profit partnership for education, research and policy development on innovation for sustainable development.

The initial 2002 TNEP team included young engineers Charlie Hargroves, Cheryl Desha, and James Moody each having been presidents of state chapters of Young Engineers Australia. The team sought and gained support from Engineers Australia and CSIRO to compile and publish *The Natural Advantage of Nations*[56]. With chapters authored by leading authorities, this text is now used widely in Australian and international universities, including in engineering schools. For this work, TNEP and its members received several national awards in 2005:

- Banksia Award for Environmental Leadership, Education and Training
- Eureka Award Finalist in the Allen Strom Prize for Education in Sustainability
- Engineers Australia Young Professional Engineer of the Year - Cheryl Desha
- Australia's Most Inspiring Young Engineers List - Cheryl Desha and Nick Palousis

Now hosted at Griffith University and the Australian National University, TNEP's mission is to contribute to and succinctly communicate leading research, case studies, tools, policy and strategies for achieving sustainable development across government, business and civil society.

TNEP's main activities involve undertaking research, creating education material and curriculum, and developing industry and economic policy. TNEP undertakes a range of action research activities to inform and further develop its research program, including delivering short courses, workshops, design charrettes, strategic planning sessions and conference presentations and to build industry experience and relationships.

Edited extracts from: TNEP website, http://www.naturaledgeproject.net/About.aspx

6.5 Increasing the diversity of students and pathways to increase graduate supply

Australian universities have relatively high proportions of domestic engineering student places taken by students from recent migrant families, and from low socio-economic status backgrounds. Engineering classrooms are often highly culturally diverse, further enhanced by the high proportion of international students. Nevertheless, amongst all identified groups, indigenous students are grossly under-represented.

Companies and universities are actively working to increase opportunities for indigenous students and graduates. The national Indigenous Australian Engineering Summer School program was started in 1999. A recent article[57] records one former participant of the school, now an engineer, reporting that the school showed *"how engineering can be valuable to the future of indigenous communities*", and the importance of having role models to encourage future student participation, a point that has already been made in relation to women and to engineers as a whole.

Increasing the numbers of engineering technologists and engineering officers, as well as professional engineers will be need to be tackled in several ways, including through the actions proposed in Recommendation 6. Increasing the number of women undergraduates in engineering must be the highest priority for the whole sector. The major barriers to participation for the current generation of school students must be identified, and appropriately focussed *Women in Engineering* programs should be linked to curriculum reform, as discussed earlier.

The education sector must work with employers to understand and lower the barriers to women engineers seeking to re-enter the engineering workforce or take part-time employment. The evidence referred to earlier shows that engineering workplaces have not, in general, adapted as well as other professions to the contemporary needs and expectations of women, or indeed families. The higher education sector could support re-entry of professionals through the provision of appropriate study materials more effectively.

It is likely that elements of this approach could also be used to support migrant engineers to upgrade their skills and transition to Australian workplaces more effectively. Here too, research is needed to understand the specific barriers to success in engineering for migrant engineers.

Several universities have started to use aptitude testing of prospective students who do not have the standard pre-requisites for engineering study. For example, in 2007 the Australian Technology Network introduced the Engineering Selection Test (ATNEST) as a "*two and a half hour multiple choice test that assesses a candidate's aptitude to think scientifically, solve quantitative problems, critically analyse information and display interpersonal understanding*" [58]. The outcomes of this approach to increasing commencing student numbers have not yet been published.

Naturally, the engineering program taken by these students must contain a suitable set of 'bridging' courses to enable the students to acquire the course content that they had missed. Such an approach is not new: many universities have operated bridging, 'access' and 'foundation' programs for years. Coupling them with an aptitude test, however, puts them in a more positive light. An alternative approach adopted by the University of Sydney has been to offer a general three-year Bachelor of Science & Technology[59] from which selected students can transfer to the third year of an engineering program.

Other study pathways for engineering could be enhanced further, for example by:

- introducing postgraduate programs that are aimed at science degree graduates and include professional engineering components could be devised for particular engineering specialisations;
- improving the interfaces between VET qualifications and degree programs, specifically managing the development of mathematical material more successfully than has often been the case.

The successful provision of such pathway programs requires adequate numbers of students. Each engineering school needs to consider how it can best improve its own position and contribute to the overall provision of graduates through inter- and intra-state collaboration.

7 Developments in undergraduate engineering education

7.1 Introduction

The *Changing the Culture* review promoted many improvements in the engineering education system, most notably by increasing the focus to graduate attributes in both accreditation and curriculum design. Nevertheless, the submissions and consultations to the study have shown continuing concerns with content and methodology, and their effectiveness in graduating engineers having the desired qualities needed for future engineering. Most consulted consider that further curriculum changes and development will be essential to maintain student numbers and meet students' expectations satisfy employers and the profession at large.

There is current worldwide interest in improving engineering education, and many Australian educators contribute to international forums and conferences on the evolving philosophy and practice of engineering education. In fact, education for professional engineering has roots in both the practice of skilled crafts and in the development of physical science and mathematics. The practice tradition dominated the 19th and early 20th century approaches to formal engineering education in the UK, while France promoted the engineering science model[60]. Other nations developed their engineering education around both traditions, often with two types of educational institution. For professional engineering worldwide, engineering science became increasingly important in the curriculum from the mid-20th century, in parallel with its increasing power to model increasingly complex engineering applications. Most engineering curriculum development has followed the models, curricula and materials (such as standard texts) developed in the USA, with very strong early year emphasis on courses on fundamental mathematics and science, and some studies in the humanities. Australia's engineering curricula have adopted this pattern, although, in common with UK, have consistently had more engineering design and project content and less science and humanities than has been typical of American degrees. The longer duration professional degrees in northern Europe and Scandinavia have permitted both fundamentals and design to be covered in greater depth than in Australia.

As we progress further into the present century the importance of ensuring that engineering is done well, and that graduates are "*ready to engineer*" as the proponents of CDIO[61] put it, has challenged engineering educators to think well beyond the scientific fundamentals. The importance of educating for engineering practice is, in a sense, being reasserted. So it is against this background of the emerging needs for effective and ethical practice with minimal impact on the environment, together with the opportunities offered by new science and technologies, that contemporary thinking about engineering education is taking place. The findings and outcomes of work in the area of engineering science and practice being undertaken by the Senior Carrick Fellow, Professor Ian Cameron, will further assist the development and refinement of Australian needs and curricula.

The curriculum focus of the present study has been almost exclusively on undergraduate education. The following subsections summarise views and emerging issues in each of several key areas: graduate outcomes and attributes; engineering education methodologies and curriculum innovation; mathematics and science in engineering; engineering practice; engineering management; and multidisciplinarity.

The illustrative examples of good practice are provided largely from the material provided by deans.

7.2 Graduate outcomes and generic attributes

Through the development of the accreditation process based on graduate attributes (summarised in section 3.2), and more recently in the Stage 1 Competency Standards, Australian engineering has been a leader in what are now common university-wide statements of generic graduate outcomes, as well as in the international accreditation arena. Explicit focus on generic capabilities (including problem solving, communications, teamwork, ethics, and lifelong learning) is supported by industry, and engineering graduates respond positively in their reflective judgments on attainment of generic skills.

Nevertheless, contributors from industry have reported great variations between graduates' performance: the best are said to be "*brilliant*" and some are described to be "*unemployable*". The most common general criticism of graduates by members of the business community, in engineering and other disciplines, is that they have poor communication skills, particularly in business-specific writing. On the positive side, most employers acknowledge that today's engineering graduates are better oral communicators and team-workers than their predecessors. Not surprisingly, they are also judged to be better at using software tools.

The Carrick Institute funded project on meta-attributes for engineers (refs 25) has examined the issues of teaching, assessing and embedding graduate attributes. Their submission to this review reported on "*a series of hurdles that constrain graduate attribute teaching*", some of which relate to academics' capabilities and the leadership of the academic program, resources and organisational issues. Other hurdles are lack of clarity about the definition of the attributes themselves, and lack of knowledge about good teaching and assessment of them. That project has drafted a matrix (ref 26) describing the evidence undergraduates would need to produce to claim competence in each of the graduate attributes defined by the Engineers Australia accreditation process. Such documentation should assist 'top-down' curriculum design of engineering programs, but there remains much evidence of fragmented and inefficient (eg overlapping) curriculum design, and delivery and assessment practices.

Some of the confusion about implementing graduate attributes has been the extent to which they are truly generic, that is relevant to all or most disciplines, or are specific to engineering. The confusion may have been exacerbated by the parallel development of university-wide graduate attributes or qualities, even though having both engineering and university sets are mutually reinforcing. Conflict can arise if university policy requires an approach to teaching one or more of the qualities that is not well suited to the learning styles of typical engineering students.

The intention of the proponents of generic attributes in engineering is that they should be embedded in curricula rather than specifically taught: in a systems sense some of the graduate attributes are ***emergent properties*** of the education process. Expressing them as major goals of the curriculum may have contributed to reducing the focus of engineering curricula on some of its traditional and essential content. This may contribute to employers and professional engineers commenting that modern graduates have: a lower grasp of "*fundamentals*"; less ability to "*work things out from first principles*"; are more reliant on software tools than desirable; and are unable to "*independently validate computed answers*". Many academics have expressed related concerns in terms of having to work with students' average lower levels of attainment in school mathematics and science, and the restricted time available in the curriculum to cover more material in greater depth.

Engineering-specific graduate outcomes and attributes

Some of the discussion in the consultations focussed on examining what is specifically generic about engineering that must be included in the curriculum. Each major engineering branch – chemical, civil, electrical, mechanical, etc. – has its own defining repertoire of underpinning science and technology, and specific engineering science, technologies and methodologies of practice. (For example, the set of scientific principles and physical materials used in civil engineering is quite different from that of computer systems engineering. CSE has existed for only three decades, and has been taught virtually independently of civil engineering.) So can unifying or common themes of engineering itself be identified in such a way that they form core outcomes of all engineering education programs?

There is general agreement that the engineering curriculum must focus on education for "*creating what does not exist*" in the form of new physical and information technology systems, products, artefacts, technologies, or processes with minimal negative impacts on the environment and people, at an economic price. Emerging from the consultations was the view that engineers do their work by having knowledge and skills in varying combinations of the following thematic areas:

- the engineering life-cycle of concept, design, implementation and production, operation, maintenance and retirement; with increasing emphasis on:
    - dealing with uncertainty and risk assessment;
    - systems thinking, and integrating ideas and technologies;
- managing complex engineering projects, including deploying resources (logistics, people and money) with maximum efficacy, in a range of time-varying and broad ranging contexts that include political, cultural, social, legal, business, environmental, health, safety and other influences;
- mathematical modelling (of physical systems and information processes) and using such models in engineering tools;
- scientific knowledge of established and emerging areas (eg at the interfaces between traditionally defined areas, increasingly in areas that involve biological sciences, technology and systems).

Whilst all these thematic areas are important, they would be expected to have different degrees of expression across the range of degree programs offered in Australia. As discussed in section 2.2, future education programs for professional engineers may need to be designed more clearly and purposefully for practice in advanced engineering science and technology on one hand, or in systems integration and project management on the other. Programs for engineering technologists may also need to have similar and other differentiation of focus.

The life-cycle and project management themes may already be included in professional engineering programs in the courses and projects that involve engineering design and engineering project management, in individual work and in teams. In few of today's undergraduate curricula anywhere around the world, however, are all of the areas brought together systematically, or used as defining themes. There is general agreement that current engineering curricula do not deal as well with the difficult topics of uncertainty, integration and complex systems, as they do with component-level modelling. For example, the biological interfaces are quite underdeveloped in current engineering programs. Several contributors to this study observed that the biological sciences will increasingly shape much of the future development of engineering innovation. There thus exists considerable opportunity for curriculum development in such areas, that, implemented well, could more adequately meet some employers' expectations, and be attractive to prospective students.

Within the engineering life-cycle, the current educational focus on construction, operation, maintenance, and logistics is generally quite weak, despite their importance in business value chains. Indeed, the construction engineers have indicated strongly to this study that most civil engineering programs are deficient in their area, despite the strong employment opportunities offered.

Whilst the study has sensed willingness amongst leading engineering educators to address these emerging issues, there is relatively little experience in the sector of leading and implementing major top-down curriculum review. Engineering academics' skills in curriculum conceptualisation, design and pedagogy need to be developed and rewarded (see Recommendation 4).

7.3 New methodologies and directions for innovation in engineering education

Much of the international focus on engineering education is addressing similar concerns to this study. Educators want more students to engage in learning that leads to graduation and successful professional careers. Education programs should be enjoyable for their students. Many students contributing to this study made it clear that they are not averse to a high workload when the material is interesting and can be seen to be purposeful and "*relevant*", as most of them put it. They also expect engineering programs and courses to be well designed, and competently delivered, an issue discussed further in Chapter 8. Employers want work-ready graduates capable of tackling unseen tasks. Dealing as it does with commencing students with highly variable attainment in mathematics and science and complex lives, engineering education needs to be systematic and adaptive in approach, and educators need to adopt and adapt successful innovations and methodologies to their local needs.

In conceptualising and implementing change, educators must focus on the learning attributes of students. Even more than their predecessors, GenY students are likely to learn best from active-learning approaches, including project and problem-based learning (PBL). Most educators agree that there are specific roles for the classroom lecture and highly prescribed laboratories, but that these methods should not dominate curriculum delivery. Student engagement and positive learning outcomes can be increased through participative assessment methods such as self- and peer-assessment[62]. In areas like basic mathematics, where lectures are a proven way of guiding students through new material, episodes of student activity can promote more effective learning[63]. Curriculum designers need to recognise that few GenY students will have had 'engineering hobby' experience in mechanical and electronic work as the baby-boomer generation did, although most will be highly proficient at using the internet and other software tools. The need to adapt to the background and learning needs of individual students is a challenge within a resource constrained environment.

Active learning

There are already acclaimed examples of active-learning techniques (see Box 3) in engineering education in Australia, and scope for more widespread adoption of this methodology. The engineering schools at the University of Central Queensland and Victoria University[64] have adopted problem-based learning for the whole of their undergraduate programs. The engineering systems streams in the pre-requisite bachelor degrees that lead to admission to the Master of Engineering program in the new Melbourne model also incorporate PBL. There is also a rapidly growing international literature on problem-based learning in engineering to assist adopters to avoid major pitfalls in design and implementation[65].

The CDIO concept, based on experiential learning theory, is probably the most important recent formal development in engineering education. Its "*learning activities are crafted to support explicit pre-professional behaviour*", (ref 2, p 32). CDIO is evolving towards an international network and system of supporting resources for improving engineering education systematically. Much of the CDIO philosophy is absolutely in line with the expressed focus of most Australian engineering schools, so its ideas are not revolutionary in the Australian context. For example, many Australian engineering schools have included a first-year course on engineering principles and design[66] for several decades, yet such a notion appears to be radical amongst some of the prestigious American and Swedish schools that have initiated the CDIO project.

The published CDIO framework is very useful however, and following the conference workshop on CDIO at the AaeE 2007 Melbourne conference, several Australian universities have signalled their intention to follow through with implementation of some of the proposed curriculum actions under Recommendation 3. Some Australian engineering schools might, for example, want to place a greater emphasis on the implement and operate phase of the CDIO cycle, to meet the needs Australian industry. The ability of all Australian engineering schools to implement CDIO to the highest standards is very much limited by the resources available to the schools and the richness of their industry linkages.

Box 3: Examples of project and problem-based curriculum in Australian engineering schools

The University of Queensland designed and implemented a project-centred curriculum in chemical engineering in 1995, graduating its first class in 2001. The curriculum design focuses on developing all the graduate attributes. Students work in teams for at least one course of each semester of all years of the program, with remaining material designed to complement learning needs identified by the students in the projects. The program won the 2005 Australian Award for University Teaching (Enhancing the Quality of Student Experience).

The University of Southern Queensland has restructured its undergraduate engineering programs to incorporate a suite of problem-solving courses. These are novel in so far as they foster interdisciplinary teamwork across engineering disciplines and program levels, and are operated with both distance and on-campus students. The development has won AaeE and Carrick awards for their innovations in teaching and student assessment.

Edited extracts from the Deans' submissions on innovations

The essential technical content of contemporary engineering is based on scientific fundamentals, expressed in mathematics. Neither the fundamentals nor the mathematics are necessarily easy to understand (eg. thermodynamics, electromagnetic theory and quantum theory are hardly intuitive, but all are of core importance to mechanical, electrical and electronics engineers, respectively). Good curriculum design and sound pedagogy that build on students' prior knowledge must be employed. New ideas, such as 'learning through variation'[67] and 'threshold'[68] learning, are being applied, evaluated and most importantly, disseminated for others to adopt.

Curriculum inclusivity

A further dimension of educational innovation that many would welcome would be greater adoption of inclusive principles in the curriculum, to better engage women and other minority groups. Indeed the predominantly intellectual, teamwork and problem-solving elements of contemporary engineering practice should suit women just as well as they do men. Nevertheless, students and others have observed that engineering curricula (and physical science texts) tend to be crafted with over-use of masculine stereotypes and examples, such as automobiles, rockets and weapons. One academic reported to the study that there is evidence from outside Australia that using the example of a blood-pump rather than an automobile fuel pump increased female students' understanding of the relevant mechanical principles, with no change to that of the males'.

It has also been noted that the workload issue referred to earlier can be conveyed by some engineering students (mostly male) and others, with a certain competitive arrogance and even contempt for non-technical material (often unhelpfully described as 'soft-skills') and of students majoring in such disciplines. Such attitudes certainly inhibit change in the directions set by *Changing the Culture* and may continue to undermine curriculum and other innovations that most believe are essential to both increase participation in engineering education and improve the effectiveness of engineers in practice. It must also be noted that some students encountered in this study, including women, challenged the notion that engineering is 'gendered' in the ways that have been described above.

Experimental and laboratory work in engineering

The Engineers Australia accreditation system places significant emphasis on engineering application skills development and this includes the laboratory and practical capabilities with emphasis on the scientific method, experimental design, testing, verification, skills in the selection and application of models, application of appropriate laboratory procedures including sustainable and safe practices and skills in interpreting credibility of outcomes and documenting results. All the consultations were strongly in favour of retaining and indeed strengthening the practical content of engineering programs.

The role of laboratory work was also discussed in several of the consultations with students. They are rightly critical of laboratory equipment that does not work. One group of students suggested that engineering would be served better by 'professionally oriented' laboratory work than by 'science' oriented approaches. This implies that engineering experiments should be more about testing the limits and validity of design than about 'proving' an established scientific fact or relationship. One group of academics suggested that the use of the word 'laboratory', with its historical association with discovery science, is hardly appropriate for contemporary engineering: alternatives could be 'design studios' supported by workshops and testing facilities.

There are deep and widespread concerns about the ability of engineering schools to adequately fund and staff laboratory and practical design work (see Chapter 8). Curriculum designers need to be clear about the purpose of laboratory activities, making them as authentic as possible (that is relating the activity to current industry practice) with respect to the technology and measurement techniques explored. The introduction of remote laboratories and increasing use of software simulations has raised concerns amongst some academics and members of industry, but properly done, such techniques can increase the learning value. Simulations, in particular, allow students to explore limiting and failure modes of engineering phenomena and systems beyond what is possible with physical equipment either in the laboratory, or in the field. Engineering students rightly expect to get their hands on real hardware. Ideally, students should engage with the theoretical underpinnings, simulation, laboratory-scale and full-scale implementation of engineering systems and processes.

Program structures: the 'common first-year' and advanced programs

Most four-year professional engineering programs have a common structure with fundamental mathematics and science in early years, and progressively more discipline specialisation in subsequent years of study. The first-year of most programs usually includes an introduction to the engineering profession and engineering life-cycle, with several now introducing design activities.

Box 4: The Engineering Foundation Year (EFY) at Curtin University

Curtin Engineering has revised its curriculum to meet the demands of the profession. Critical in this educational experience is the first year program. There is strong evidence to suggest that the performance of students in first year is often related to the social context and networks that they can establish in the first few weeks at University. For these reasons, Curtin has now established a common first year curriculum for all engineering students. The EFY has a dedicated office to provide students with pastoral and academic support.

The EFY cross-disciplinary curriculum has been designed to provide the skill base required for student to progress smoothly into the commencement of discipline-specific engineering studies. Complementary to the program are the purpose built learning facilities of the EFY studio which were created in partnership with industry sponsors to reflect a microcosm of engineering professional practice. The EFY learning environment and community endeavours to facilitate students' transition into university style study and life, with retention-rate benefits for the university and society.

The EFY introduces students to the components of engineering practice. Importantly, they gain an appreciation of the role and functions of engineers, and of the various sub-disciplines.

The range of integrated learning activities in the EFY program includes: traditional full-class lectures; small-group tutorial work; hands-on laboratory work; industrial site visits and follow-up case studies; team-based design and simulation projects; using a web-based learning tool as a resource, bulletin boards, online tutorials and quizzes; personal portfolio development with an emphasis on reflection and self-evaluation.

Edited extracts from: http://fac.eng.curtin.edu.au/EFY/

The merit of operating a first-year program with the same set of subjects for all engineering students is a matter of continuing debate. The 'common year' at Curtin University of Technology, see Box 4, has seven common courses, with the eighth set aside for bridging (for students who had not taken a full physics or chemistry subject in their senior school certificate) or one of a number of more options related to engineering.

Other versions of 'common first-year' programs use a common structure across engineering disciplines and common mathematics and science (including computer science) and an introduction to engineering of the form referred to earlier, plus a choice of two or three engineering subjects covering introductory material in civil, electrical & electronic, mechanical and chemical engineering, etc. As such, these subjects serve both as introductions to areas of engineering science, and assist students to make their discipline choice.

Academics generally report that about half of the students commencing engineering have already decided on which area of engineering they intend to pursue, and that there is not much cross-over between those who chose the electrical, electronics and computer engineering family, and the other engineering disciplines, particularly civil engineering. Some of the students who have made a firm discipline decision report that they find some elements of the common first year a frustrating experience. Clearly there is no single solution to successful program design and implementation that can satisfy all students; and educators must be mindful of the range of students' aspirations.

Advanced engineering programs

Some universities have introduced 'advanced' engineering programs to attract students with exceptionally high secondary school certificates to engineering. Box 5 outlines different approaches used by Queensland University of Technology, the University of Sydney and Monash University. All these programs endeavour to address many of the broader concerns of industry for the quality of engineering graduates.

Other observations on engineering curricula

The preceding paragraphs have provided illustrations of some of the curriculum innovations that are already being accommodated within existing current program structures. Including the many dual degree formats, engineering students in Australia can experience a very wide range of curriculum approaches that, ideally, match their abilities and interests. Any particular industry group or member of the profession may be unaware of the innovation and range of curricula in operation through their contacts with graduates and programs. The engineering schools may, therefore, need to communicate more effectively with industry the rationale for their particular approach, as well as ensure that the best possible standards are achieved.

Some contributors to this study, mostly but not solely from industry, have called for more radical change. One submission proposed *"throwing out the engineering curriculum and its discipline divisions … and start over with specialist technical "scientific" qualifications and an over-riding "engineering" upper level where broad technical knowledge is married to management skills"*. This submission also abhorred the *"MBA style of management"* and the antagonism between the engineering disciplines. Perhaps some of the current program developments and several of the proposals made here address aspects of this call.

Most of the individual submissions called for building stronger curriculum links to engineering practice, discussed further below, and many referred to the importance of project work. Other submissions considered that the engineering program is already too long and intense, and fear the introduction of a 5-year qualification requirement. 'Inverting' engineering programs so that more advanced science and mathematics can be provided after a sound understanding of practical engineering was also suggested.

Box 5: Advanced engineering programs

The Queensland University of Technology Deans Schools Program, introduced in 2002 has provided more than 100 high quality students (achieving OP1 level in the senior secondary certificate) with a dedicated program of engineering excellence and leadership. These students might otherwise have been lost to engineering. The program offers the opportunity of accelerated study, so that the B.Eng and 1 year coursework masters degree can be completed in 4.5 years of study.

The program has external sponsorship, and provides its scholars with individual professorial mentoring, boardroom exposure and networking opportunities with senior external and academic leaders.

Edited extracts from the Dean's submission

The Advanced Engineering Program at the University of Sydney commenced in 2006 for students who have proven outstanding academic ability (a UAI of 98 or higher). The program is available in all engineering disciplines and continues in Year 2, 3 and 4.

The program offers first year students the opportunity to defer physics and mathematics, and work in a supervised groups research and project, from premise to working prototype. The projects address humanitarian and sustainability issues such as: clean water, improved housing, solar pumps, innovative transport, food preservation, information dissemination and electricity generation. Subsequent years of the program include business planning, education outreach to Year 9 school students, and, in final year, an inter-disciplinary engineering project.

Edited extracts from: http://www.eng.usyd.edu.au/apply/ advanced_engineering.shtml

Starting in 2007, Monash University offers 50 $6,000 Engineering Excellence Awards annually to commencing students achieving an ENTER of 98.00 or equivalent. These students are eligible to participate in the Leadership in a Technological Environment program. This program is designed to produce engineering leaders of the future, providing participating students with a unique opportunity to network, acquire skills and learn about leadership outside the classroom. The program includes a two-day residential workshop, and nine short modules (in areas including critical thinking, sustainability, innovation and entrepreneurship) spread over three years, as well as regular seminars from industry and research leaders. Shadowing and interviewing industry leaders, practical activities, team building and personal development exercises form an integral part of the program mix.

Edited extracts from: http://www.eng.monash.edu.au/prospective/

7.4 Mathematics and science in the engineering curriculum

Mathematics and statistics

Mathematics is both critical and contentious in the context of engineering education. Being able to manipulate mathematics in logical reasoning and to model the behaviour of physical systems are critical to understanding engineering science, and engineering analysis and synthesis. As discussed above, school mathematics is the defining pre-requisite for studies in engineering. Failure in mathematically intensive courses in the early years of engineering study is a major contributor to the relatively high attrition rates in engineering. To cater for the range of levels of mathematics attained (see ref 44) many engineering schools have negotiated with their mathematics colleagues to offer alternative or streamed mathematics courses. There has been a general trend to reduce formal and dedicated mathematics courses in engineering programs, to typically two first-year courses, and one in second year. A significant portion of first-year mathematics study frequently reinforces the high school curriculum in order to ensure foundations are in place.

Opinions on the necessity of high levels of mathematics in undergraduate engineering programs vary widely. Much of engineering practice is not highly mathematical. In this study, several practising engineers asserted that their university mathematics was a "*waste of time*" in so far as they declared that they have never used the advanced techniques they were taught. More of them stressed that it is important for engineers to understand the mathematics and scientific fundamentals behind the software tools and techniques they are using, and have the ability to validate (intuitively estimate) quantitative outcomes of simulations. Several industry contributors suggested that graduates need greater understanding of modelling distributed systems, data analysis and statistics, and probabilistic modelling of risk assessment.

Many academics, not surprisingly, given the dominant engineering science paradigm of engineering education, stressed the absolute importance of high levels of mathematical competence, some with the implicit meaning that this competence is necessary for students to succeed in their particular advanced course. Some, however, also echoed the concerns of industry: referring to the value of including more statistics and probability in many engineering areas, the need for systems level mathematics, and the relatively low level of mathematics needed in civil engineering. They also expressed concerns about the very low level of mathematics in VET qualifications that makes articulation into university programs very difficult.

Students also expressed a range of views about mathematics. The majority view was that mathematics is generally disliked but accepted to be necessary. A minority, mostly those heading towards research careers, desired more. All students agreed that mathematics topics should be illustrated by engineering examples, or be integrated with engineering. Some of the best mathematics teaching was described as having been given by a mathematics-qualified academic, but located in an engineering discipline. The formal (as opposed to self-learned) introduction of ***one*** suitable mathematical and modelling software program such as MATLAB® was also strongly endorsed by students in most discipline areas. Some students described their experience of needing greater understanding of probabilistic modelling in their work experience. A small number of students with a VET background confirmed that the transition to university mathematics is daunting and difficult.

These insights are broadly consistent and should inform future development of mathematics for engineers. In the course of the consultations, the following further points were made that could improve the effectiveness of mathematics and statistics in engineering:

- team-teaching between mathematics and engineering, in curriculum design and all levels of engineering, using common nomenclature where possible;

- consideration of 'inverting' the curriculum to support higher levels of mathematical content in later years, rather than all during the first two years, after which time it may be forgotten;
- provision of mathematical refresher courses to practicing engineers who are not necessarily using mathematically based software tools to their best advantage;
- working with engineers and the school education sector to make mathematics at all levels more enjoyable and rewarding.

Some of these and other relevant issues will have been explored in greater depth in the parallel Carrick discipline-based project on engineering mathematics[69]. The engineering education sector would also welcome more national uniformity in the provision of school mathematics. Barrington and Brown[70] have reported considerable variation of mathematical content in the senior secondary school subjects between the Australian states. This has impact on engineering curriculum design and content, particularly at the Australian Defence Force Academy where intakes include students from all states and territories.

Science for engineers

The science component of engineering programs raised much less discussion than mathematics. The general dislike and low participation in school physics by women was referred to in a number of consultations as a reason for the low female participation in mechanical and electrical engineering. The higher proportion of women taking school chemistry has unsurprisingly contributed to greater take up of biomedical, environmental and chemical engineering.

Students commented that the science studied in their engineering programs should use engineering examples wherever possible. When taken in common courses with science degree students, some students reported that they found physics too difficult and rigorous for their engineering needs. As for mathematics, students articulating from the VET sector are at a disadvantage in their science studies compared with school leavers.

Those engineering students with strong interests and abilities in science and mathematics have generally taken advantage of dual degree opportunities, in physical, environmental and computer sciences, and mathematics, and in the advanced programs discussed earlier.

7.5 The importance of engineering practice in engineering programs

Every consultation with student, industry and academic groups, and most of the submissions affirmed the importance and value of good industry experience during the undergraduate program. "*Exposure to professional practice*" is an accreditation program requirement. The baseline level of exposure to practice is some classroom material on the engineering profession and practice, and a period of three months of employment usually taken before the commencement of the final year of study. However, many engineering schools will have a small number of students unable to gain suitable work before completing their coursework, and have their graduation delayed until completion of three months of employed work. This is far from ideal since the intention is to integrate exposure to practice alongside tradition learning as an integrated skills development approach. Improving the quality and intensity of undergraduates' exposure to professional practice was a strong theme in the *Changing the Culture* recommendations, and has not been adequately addressed across the educational sector. In consequence this need underpins several of the actions in Recommendations 4 and 5 of this study.

The highly diverse and distributed nature of engineering practice makes it much harder than medicine for example, to provide all undergraduate students with a common and comprehensive exposure to practice. Engineering schools have adopted a range of approaches:

- formal industry-based learning programs that are well regarded by industry and students, see Box 6;
- cooperative education schemes with students having a range of period of time spent in industry;
- a high proportion of final year engineering projects sourced from industry;
- site visits to engineering plant and sites, noting that these may are time-consuming, expensive and disruptive, especially with large student numbers;
- industry professionals providing guest lectures, or in some cases, conducting whole courses, noting that the latter is not necessarily easy for the engineering school, or industry to manage.

Box 6: Examples of Industry-Based Learning in Australian engineering schools

The University of Technology Sydney operates its standard engineering program with two semester-long industry internships, after two and five semesters of coursework. Industry welcomes the internship students, offering many with full scholarships (cadetships), part-time work and full-time employment after graduation. Each period of industry practice is formally previewed and reviewed, with graduates, gaining the additional award of Diploma in Engineering Practice. The successful operation of this program over many years contributed to the 2007 BHERT Award for Industry Collaboration to the UTS Faculty of Engineering.

Swinburne University of Technology also operates an IBL program in engineering as a full-time paid placement in industry for usually 6 or 12 months. Many students undertake their IBL program in international companies. This program was enhanced in 2007 by the signing of a Professional Development Program (PDP) agreement with Engineers Australia so that its participants can gain status in up to five of the post graduation (Stage 2) competencies required for chartered status of Engineers Australia. This is amongst the first agreements of its kind for an Australian university.

Edited extracts from the Deans' submissions on innovations

All of these measures can assist to compensate for the fact that progressively fewer engineering academic staff have recent industry experience (other than in research laboratories) that they can use in the classroom than was the case even two decades ago. Submissions from industry practitioners reported that few engineering graduates, other than those in civil engineering, have much familiarity with industry standards and codes when they commence employment. Students confirmed this. There was also some debate amongst industry participants on the extent of familiarity that professional engineering graduates should have; but general agreement that graduates should understand that engineering is a 'constrained creative practice' of "*problem-solving under* *financial tyranny*" as one contributor put it. Teachers with current or recent industry experience can bring these dimensions into the classroom. Several of the actions proposed in Recommendations 4 and 5 are intended to improve the curriculum through strengthening connections between industry and the engineering schools. Section 4.9 describes further connections between specific industry groups and the engineering schools.

7.6 Management courses and interpersonal skills development

Management courses have been incorporated within undergraduate engineering curricula for several decades, explicitly meeting accreditation requirements over that time. Courses that follow the standard Australian text[71,] first published in 1989, would provide students with foundation level coverage of contextual topics (such as macroeconomics) and several topics of direct relevance to early career graduate engineers, such as engineering project management, operations management and managing engineering design. Many of the chapters of this book are authored by senior managers and academics with engineering qualifications, and the book has the premise that that much of what engineers do are managerial activities, such as "*planning, organising, controlling, leading, directing, allocating resources, communicating and co-ordinating*". Much of the evidence presented in this study indicates that an education that prepares engineering graduates for this set of activities remains at least as relevant to engineering practice today as it did 20 years ago.

A common view in most of the consultations was that general management topics should be left until after periods of industrial experience, and also that there is scope for curriculum improvement. Several contributions emphasised that it would be desirable to concentrate on engineering-specific project management functions separately from the more general and contextual introduction to business and management. The former could be taught as an engineering skill and used in early years in project work.

When questioned directly, students have indicated that they are not necessarily required to use or be assessed formally on the project management aspects of their final year project work. This is surprising, since a major learning objective of undergraduate project work should be on how to conduct a fairly complex, broadly based and open-ended project and certainly one on an 'unknown' topic or in an unfamiliar context, such as they are likely to experience in industry. While students undertaking construction or project management majors would expect to cover the specific project management thoroughly, there could be a lost opportunity to prepare many graduates in the skills expected by industry.

An operational issue is the extent to which schools of faculties of business and management should be involved in the development and delivery of management topics in engineering schools and their students. Some engineering students and employers indicated that standard management material, as provided for students studying for management or business degrees, does not provide engineering graduates with the toolkit of skills and knowledge that they need. While each university will have a policy and position on inter-faculty 'service-teaching', the occupational requirements of engineering and the important position of engineering within the business domain (see 4.8) deserves more attention. The strong relationship between engineering and business could open the possibility of enriching the management for engineers with team-teaching and case studies and guest lecturers. As discussed earlier, inter-faculty collaboration on engineering-specific MBA programs also deserves consideration to meet industry and graduates' career needs.

Graduate engineers are often criticised for lacking management and people-skills, and as reported earlier, as students may even disregard their importance to their future work. Many of the activities proposed in the CDIO framework are intended to address this, and many Australian engineering schools have already taken steps to develop students' generic attributes. A notable example from the University of Adelaide is summarised in Box 7.

Extra-curricular activities such as participation in the Students in Free Enterprise[72] (SIFE) movement have provided engineering students opportunities to develop personal and teamwork skills around a business concept, often in multi-disciplinary groups. Design-oriented national and international engineering competitions such as the Formula SAE[73] car, Engineers without Borders (EWB)[74] and the annual Weir-Warman Design and Build competition[75] have been brought into engineering curricula in many universities, enhancing both technical and non-technical skills development. A challenge to engineering educators is to ***mainstream for all students***, the ethos of student enthusiasm and positive outcomes that such activities engender.

Box 7: Roleplaying: online and face to face

Professor Holger Maier, University of Adelaide has introduced a roleplaying activity in 2nd Year environmental engineering. This uses a custom-built online simulation tool (e-Sim) for situational learning. The roleplay typically involves 60 – 140 students who adopt the roles of stakeholders (government and non-government organisations, engineering firms, villagers, and development agencies) and respond to proposed development issues, such as a large-scale hydropower proposal for the Mekong River basin. This region provides an authentic setting for complex student interaction, giving insights into multi-disciplinary and multi-cultural issues. Students undertake research in their assigned role and the project context and gain understanding of complex decision making. They learn to see engineering projects from multiple perspectives, and build and argue a case for or against the proposed development. They learn the meaning of sustainable development and practise teamwork, communication, research and critical thinking skills. The setting takes Australian students outside the familiar, while providing international students with a sense of place, to the benefit of both groups.

Prof Maier was awarded the 2006 AaeE engineering educator award for this work.

Edited extracts from the Dean's submission on innovations

7.7 Multidisciplinarity in engineering and emerging areas

The *Changing the Culture* review encouraged engineering schools to develop curricula that would enable graduates to work across disciplines within and outside engineering. The judgement at this time is that there has been only small progress in curricula, although a reasonable growth in multidisciplinary research.

Curriculum collaboration between engineering and non-science based areas

Although engineering practice invariably takes place in business environments, apart from the contextual introduction to management (as discussed above), there appear to be few peer-to-peer curriculum links with management schools. An exception could exist in the area of project management, but in reality, few Australian management schools appear to have strong programs in this area. Collaboration with environmental management is discussed later. Opportunities for engineering students studying dual degrees with management to undertake projects that explicitly take advantage of the combination of their knowledge areas seem to be rare, and could merit further development.

More likely candidates for interdisciplinary cooperation outside science-based disciplines might be expected between civil and environmental engineering and urban and regional planning. In practice, however, the traditions of the latter area are in geography and social science. Whilst some faculties and schools have co-located relevant areas of engineering and planning, the undergraduate programs in the two disciplines have tended to remain completely separate. Since as professionals, planners and engineers often work alongside each other on projects, there may be a missed opportunity to improve the educational effectiveness of both disciplines through, for example, common final-year project work. The growing importance of the concepts of pragmatic sustainability to both disciplines would be a natural unifying theme, to which both groups would bring their expertise. A further intersection that also lies in the domain of the built environment is the building or construction management area. Although several civil engineering degrees have a construction major, there was some evidence that these are neither sufficient in number nor sufficiently comprehensive in their coverage of the construction area to fulfil the industry's needs.

One genuinely multidisciplinary program is the Product Design program at Swinburne University of Technology (see Box 8). From an engineering-philosophic position this is particularly interesting because it combines two disciplines that both place 'creativity and design' at their core, yet rarely work together either in education or in research.

Box 8: Product design engineering: human-centred design

Swinburne University of Technology introduced Product Design Engineering in 1996. The program integrates Engineering with Industrial Design. Although the two disciplines appear, at first glance, to be very diverse, they have been successfully integrated within an academic curriculum in such a way that they complement each other. Engineering courses are followed by design courses that require the use of engineering knowledge for a complete product design. For example, after the study of thermofluid systems, the students are given a project to design a portable air conditioning unit that requires creativity and engineering innovation to achieve an attractive unit that will be placed within a household environment while being an efficient heat pump to provide the cooling comfort required.

The program has inherently attracted more female students, on average 20 – 30% per year, due to its human-centred design approach, more than double the average uptake of mechanical engineering courses by females in Australia. The employment of graduates from this course has been very encouraging as most students, if not all, find employment prior to their graduation. Companies employing these graduates range from those purely in industrial design through to engineering with the automotive industry employing the most.

Edited extracts from the Dean's submission on innovations

Multidisciplinary collaboration within engineering and with science-based areas

In common with most academic and professional disciplines, knowledge growth takes place at either both disciplinary core and at the interfaces with other disciplines. Engineering itself encompasses many disciplines, and some of the recently emerging ones, such as mechatronics and biomedical engineering embody their inter-disciplinarity in their names. Others, like software engineering, are about adopting engineering principles of robustness and reliability etc. and sound project management to the creation of applications and products founded on a new area of science, in that case, computer science. Engineering curricula and activities, such as projects, have evolved to provide students with knowledge and experiences that are at the edges of their disciplines. However, few advanced level inter-disciplinary engineering collaborative activities appear to have been implemented routinely. An exception is in the new Advanced Engineering Program at the University of Sydney (Box 5).

Future curriculum developments may be anticipated in the fields of biomaterials and nanomaterials, where engineering researchers will continue to utilise emerging new science, and refine particular areas of science for potential engineering applications. How Australian engineering industry might exploit these areas in new manufacturing processes and products is hard to predict. Nevertheless, as global engineering educators, engineering schools should develop specialist programs in these areas, and some students will be strongly attracted to enrol in them. New application areas of information engineering (including electronics, photonics, computer, telecommunications and software engineering) are also likely to be driven by deeper understanding of neurological processes, as well as by increased capacity and speed of electronic and photonic devices. New education programs that combine these areas with human dimensions may become highly desirable in future years.

As well as scientific developments, other drivers for inter- and multidisciplinary curricula will be around systems engineering, systems integration and project management, and the emerging imperatives in energy, water, and sustainable product manufacture. Education in systems engineering in Australia has been largely a postgraduate activity (see Box 1) associated with military systems, although systems has formed the focus of the undergraduate engineering program focus at the Australian National University for several years. While project management is an established option in many engineering degrees, many industry contributors to this study would wish to see higher levels of such skills exhibited by all graduates. The specific importance of the construction management area has already been referred to.

In the area of sustainability, Hall and O'Connell[76] have recently discussed the importance of engineering and management of technological systems and related elements of natural systems as 'earth systems engineering'. The authors conclude their paper with the observation that *"the capacity for technological adaptation is now recognised as one of the determinants of human-kind's ability to cope with global change – and technological adaptation is what engineers do best*". In a sense, the notion of earth systems engineering takes environmental engineering to a new level, since all areas of engineering are involved and the very high degree of complexity of modelling requires very advanced computing and visualisation tools, not least to aid communication with non-technical stakeholders in decision-making.

Several Australian universities would be in a good position to develop postgraduate multidisciplinary programs in sustainability engineering or earth systems engineering that would build on sound multidisciplinary research programs in the underpinning areas. Such programs would be essential if Australia were to adopt a nuclear power solution to future low carbon emission energy generation, probably linked to major water desalination plant development. Any future adoption of nuclear power would also require the development of new and specific postgraduate and eventually undergraduate programs.

8 Resources for engineering education

Most of the deans explicitly identified the lack of resources as the most critical issue they face in providing high quality engineering programs, and it was described in one of the consultations as "*the elephant in the room*". As stated in the introduction to Chapter 4, in the decade since *Changing the Culture* all education programs in Australian universities generally have been under increased resource pressure. Staffing, equipment and library costs have risen at a higher rate than the funding index applied by the Commonwealth government. Many engineering faculties have survived and thrived because of their increased revenue from international student enrolments and research growth.

The following subsections address three issues: staffing and staff development; laboratories and equipment; and collaboration and sharing of material to increase the value of funded resources. The commentary supports many of the actions under Recommendation 4.

8.1 Staffing Australia's engineering schools

The data presented in section 4.3 show that across the system, 'teaching & research' academic staffing numbers and support staffing (administrative and technical) in engineering have declined since 1996. Research-only numbers have, in contrast, increased by more than 600 full-time equivalent staff. Research growth has a very positive impact on the engineering schools, since strong research missions are major attractors for most prospective academic staff, and operating engineering schools with strong research cultures is a goal of most engineering deans. However, as already noted, research costs generally have to be subsidised by revenue from teaching.

A recurring theme in the consultations has been the need to apply greater staffing resources to the education mission. Some consider that the increasing student-staff ratios are reaching levels that may threaten accreditation. Staff report fatigue with change and high administrative loads. Other critical academic staffing issues in engineering include:

- difficulties in recruiting new academics and retaining them at all academic levels. This problem may be particularly critical in some engineering schools with large numbers of academic staff approaching retirement, and in areas, such as mining and resource engineering where academic salaries and professional opportunities are poor, relative to those in the industry;
- the low numbers of female academic staff, particularly at senior levels;
- employment of academics and tutors with poor language and teaching skills;
- additional organisational and management complexity in employing and supporting part-time staff in teaching roles;
- the low flow of engineering graduates into research degree studies, and on into academic positions, undermines the future health of the engineering education enterprise, as discussed in section 4.4.

A number of solutions to some of these issues were discussed in the consultations, including:

- more research scholarships funded at levels that industry-competitive;
- salaries for engineering academics that match industry pay;
- joint academic-industry, and joint school-research centre/institute appointments.

The apparently poor ability to recruit engineering academics to Australia and retain them is partly a reflection on perceived status. Many academics commented that this is lower in Australia than elsewhere, with USA, Germany, India, and Japan most often cited. Even amongst the Australian engineering profession, there may be less respect for engineering academics than would be evident elsewhere: teaching engineering is not viewed as 'real engineering practice', and some industry members regard research as 'theoretical' and (thus) far removed from 'real' engineering.

Within universities, engineering academics are under increasing pressure to be both active researchers and highly-performing teachers. Many also have responsibilities for program and course management, student recruitment, and off-shore teaching. Accountabilities around research and teaching have increased markedly in the past decade. Both the LTPF and research outcome measures are legitimate performance instruments, of course, and most academics strive to achieve well in their work. Many staff report change fatigue. There remains a legitimate question of whether the current demands being placed on the Australian engineering academic system are excessive, and are fundamentally undermining the quality of achievable educational outcomes.

Supporting good teaching

To some staff with a strong motivation to excel in teaching or engage in engineering practice, the current emphasis on research growth may be a negative distraction. The introduction of the Boyer[77] notion of the scholarship of teaching into academic promotion and academic staff management has been a positive step, and such initiatives are further endorsed by teaching and learning awards, both local and national. Further on-going support must be systematically available for all academics to develop their skills in educational practice through short courses, time release to undertake postgraduate award study in higher education, and study leave.

Several universities now require newly appointed academic staff to undertake postgraduate studies in higher education, sometimes to full Graduate Certificate level. Many current staff members have also valued time release and financial support from their normal duties institutions to undertake such study, and have subsequently re-energised their teaching[78]. While such programs and courses are (quite properly) non-specific to engineering, staff can also gain discipline knowledge of best-practice through engagement in the national and international networks that are dedicated to engineering education, including the conferences and publications of the Australasian Association for Engineering Education (AaeE), the American Society for Engineering Education (ASEE), and the international Network for Engineering Education and Research (iNEER).

Within this framework of support for the engineering education scholarship, ideally there would be members of each engineering school specifically supported to engage in individual or collaborative educational innovation, and best-practice dissemination, calling on resources of the Carrick Institute and other collaborations. The establishment from around 1990 of Associate Dean positions with responsibilities for teaching and learning has certainly underpinned systematic improvements in most engineering faculties and schools. The reality, however, is that many of these have to operate across many disciplines, other than engineering alone. The more widespread creation of professorial positions in engineering education, such as have been advertised recently, should characterise the next stage of professionalisation of the scholarship of engineering education.

Good teaching in engineering implies knowledge of practice, but as reported earlier, fewer academic staff have recent industry experience than in previous decades. Some of the proposed actions under Recommendation 5 address this point. They mostly require application of funded time release or additional funded resources.

Technical staff

The age profile of some groups of technical support staff is also quite problematic. Trained technicians and technical officers can find alternative positions in industry with much higher salaries and the opportunity to work with more modern equipment (see below). Many of these personnel have an influence beyond their position descriptions, as they can be invaluable sources of practical knowledge for students undertaking project work.

8.2 Laboratory facilities and other learning spaces for engineering

Laboratory facilities in many universities are in urgent need of upgrading and renewal. In their submission (ref 32) the Engineers Australia's Mechanical Engineering College reported studies of laboratory provision in their discipline, finding considerable variation and several gaps against their expectations of the requirements for good quality experimental work.

Students also reported instances of out-of-date and unreliable equipment being used to demonstrate engineering principles and measurement techniques, which is obviously unacceptable. Many staff and some international students know of far superior instrumented laboratory-scale demonstrations of engineering systems and processes in institutes and universities in their home countries than exist in most Australia's engineering schools.

There are some examples of excellent laboratory facilities, often industry supported, and over the years, much creative design of engineering experiments and experimental systems. New developments in remote-access laboratories provide good students with good quality experiential learning on a 24x7 basis. The current development of new learning spaces (such as the one referred to in Box 4) for first year engineering is international best practice. One proposal, made at the Engineers Australia - AaeE university-industry workshop convened under the auspices of the present project, to strengthen the process of rejuvenation of engineering laboratories, was to create a national strategy for laboratory equipment operation and utilisation sustained by an industry consortium (see 4.9 and Recommendation 5).

8.3 Sharing expertise and other resources

Clearly it is unrealistic for every engineering school to provide a full suite of engineering specialisations. Even within a major engineering discipline only selected areas can be fully resourced. That selection is likely to be determined by research priorities as well as by student and industry demand. However, sharing staff expertise and physical facilities between institutions to maximise students' study choice and to provide the best-possible educational experience need to be strongly encouraged. These should also take advantage of digital technologies, so long are these are effective. Such collaborations must, however, be based on equitable principles and provide benefits to all participants. Having student load (and hence funding) ultimately accruing to only one member of a partnership would generally not be the desired outcome: ideally, the collaboration would be funding-neutral to the participating universities.

The general view of industry is that the universities compete more than they collaborate. There are however several examples of collaboration in undergraduate education that may serve as models for others. Industry-supported collaborations, in electronics, minerals and the power sector are described in Chapter 10. The most comprehensively networked academically-led project to date, supported by government and industry is ACEN (Box 9). Some of the outcomes of this project may be transported into the ALTC Exchange system.

Box 9: The Advanced Engineering Capability Network (ACEN)

The Advanced Engineering Capability (AEC) Network is funded under the Commonwealth Collaboration and Structural Reform (CASR) program. The network is intended to increase the knowledge across the system, of the many exciting initiatives that are currently underway in individual organisations and via industry sector consortia to advance our national engineering capability. These range from programs to encourage more school children to consider careers in engineering, to graduate development and mentor programs, knowledge sharing initiatives, sector renewal programs, innovation and collaborative R&D projects and cultural change programs.

The Network will address this issue of the many, disparate initiatives by catalysing the sharing of success stories from across a diversity of program types. The Network will also conduct critical analysis to distil the success factors, common to all collaborative capability-building initiatives.

The AEC Network will help expand our national engineering capability, sustain critical technical expertise and embed innovation in key Australian industries.

Network members are drawn from public and private sector engineering organisations, professional associations, universities and other education providers and the wider community. Foundation members include The University of Queensland, Monash University, Thiess Pty Ltd, Hatch Associates, Boeing Australia Limited, The Riviera Group, Engineers Australia and the Australian Human Resources Institute (AHRI).

The web portal - eLink – forms the hub of this network. In addition, members met in a series of workshops and other events to be held around the country in 2006 and 2007. The project is due to report in 2008.

Edited extracts from the e-Link website:
http://www.engineeringcapability.net/default.asp

Some individuals from industry also commented that "*since MIT have put their course materials on the web*" there should be much less individual development of courses. That this has not happened widely deserves some comment. To some extent, the provision of web-based materials is a contemporary equivalent of having a standard text-book. Learning difficult concepts and developing skills, particularly at the foundation levels of undergraduate engineering remains best-mediated through knowledgeable academics and well-designed activities, with good supporting text-books and other material. Web-based resources can certainly assist academics to develop such activities, and support their students learning. Resource networks, such as ACEN (and the MIT materials) should certainly allow academic staff to spend their curriculum development time allocation to greater effect.

Where web-based resources can also greatly assist staff is in developing curriculum for new areas, or those in which there are few staff in most engineering schools. Two examples are the Australian TNEP project (Box 2) in sustainability, and a UK package in materials science and engineering[79], both already used in several Australian universities.

Several of the proposed actions under Recommendations 4 and 5 are intended to increase academic 'productivity' through resource sharing, and the collaborative development of best-practice.

The general decline in the number of technical support staff in the engineering schools was noted in section 4.3. At the same time the numbers of supporting administrative staff in the schools may have increased, and certainly the number of academic staff employed in university-wide teaching and learning support units has increased across the sector. Nevertheless, the size and complexity of administration associated with delivering a program have increased significantly over time, and much of the work falls to academic staff to oversee or undertake directly. Preparation of program descriptions and course outlines, showing the expected outcomes, is one example. Such work has highly skilled and routine elements, and almost every institution has its own content and style requirements. Systematisation is highly desirable, and to this end several universities have developed course profile builders or similar tools. One, initiated by the University of Queensland's engineering school is described in Box 10. Clearly, such initiatives can increase academic productivity, as well as provide higher quality information resources for students, academic staff and for management reporting.

Box 10: Course Profile Builder at the University of Queensland

All engineering courses and programs now have publicly available statements on educational goals and methodologies. UQ's School of Engineering developed a web-based system (Course Profile Builder) that guides academics to design their courses within a pedagogic framework that electronically documents learning objectives, activities, assessment and how they contribute to the development of engineering graduate attributes. This has since been further developed to become a university wide system through which all course information is provided and made available to the university and wider community. All course profiles are updated every semester; previous profiles are archived; and the system has capability to deliver various reports aggregating information at semester and program level.

Edited extracts from the Dean's submission on innovations

9 The visibility of engineering and outreach to schools

Engineering academics and contributors from industry and the profession all referred to the profession of engineering and the work of engineers as being invisible to the public. They often bemoaned their status compared with those of doctors, lawyers and accountants. Many student groups also described engineering as being invisible within their school and life experience. Those students who chose engineering reported being influenced to do so by family members, and by presentations by professionals, academics and student engineers at careers fairs, more than they are by most of their teachers.

Similar findings of low visibility have been reported in a recent UK study on public perceptions of engineers and engineering[80]. This has been a long-standing problem in both UK and Australia that has been raised in many reviews of engineering education, including *Changing the Culture*, and has been continually addressed in outreach to schools, and through the media, some of which is reported below.

This study has attempted to explore some of the reasons for this low visibility and perception of low status to guide future actions by all stakeholder groups, as proposed in Recommendation 1. The consultations raised many interesting points covered in the following subsections.

9.1 Understandings of engineering and representation in the media

In everyday parlance, the work 'engineering' has been commandeered by areas wanting to express processes and outcomes that are 'designed' for specific purposes. The emergence of 'genetic engineering' and 'financial engineering' are recent manifestations that clearly lie outside the current ambit of what is generally included in the engineering profession, notwithstanding the strong science and mathematical bases of both these areas. (Indeed many engineering graduates, particularly from the electronics area, work in the finance and banking in areas such as financial systems and financial product modelling.) Established for much longer as career occupations have been 'aircraft maintenance engineering' and 'audio engineering'. In the first of these areas particularly, 'engineering' carries the expectations and images of robustness, safety and reliability; the latter the expectation of reliable support for artistic creativity.

In describing their work, most professional engineers tend to stress the first three elements of the CDIO cycle: conceptualisation, design and implementation, as well as 'problem solving'. Engineers stress creativity but rarely talk about the scientific foundations of the models, codes, tools (both hardware and software) that they use. Advertisements for engineers usually include both a functional requirement (design, project management, sales, production, etc.) and a discipline area (civil, mechanical, etc.). To be really meaningful, the word 'engineering' almost always needs adjectival qualification.

Much of the invisibility of engineering is due to the fact that engineers generally practice at a much greater distance from the public than do physicians, lawyers or accountants. Most professional engineers, engineering technologists and engineering officers are employed in organisations, or are consulted by organisations, rather than being engaged directly by individual members of the public. Australia's geography and largely urban population add literally to the perceptual distance of many intensive engineering operations associated with the minerals industry for example, from most of the general public.

The public may have some awareness that engineers design, implement and operate the physical and software infrastructure that underpins modern society: separate potable and waste water reticulation; reliable electricity supply; reliable and secure telecommunications and computer systems and software applications; safe and reliable transport infrastructure; safe buildings; efficient agricultural systems. The public enjoys the benefits of well-designed and robust manufactured goods. The fact that these products and systems are safe, reliable, and robust, and are very hard to dismantle and fix when they fail, may diminish interest in how they have been created, and in the core professions have the knowledge and understanding to conceptualise and make them. It perhaps takes major engineering failures such as Chernobyl, Challenger, and Melbourne's West Gate Bridge, or the impact of natural events on engineering systems to raise general public awareness. Often, the examination of these events reveals that the failure is due to poor decision-making as much as it is due to bad science or technological factors. Poor engineering design decisions may arise from the inevitable compromises between functionality and cost.

Many contributors to this study, particularly academics, referred to the lack of a culture of research-led engineering in Australia that is known and celebrated as a major contributor to the economy, despite the fact that there are headline Australian companies built on engineering and minerals processing expertise. They contrasted the prominence of major (signature) engineering companies in Finland and Sweden, and identified USA, Germany, Japan, and Korea as nations with strong engineering cultures. The following statement defining engineering by Auyang (ref 4) would probably be better understood in those countries, than in Australia:

> *"Engineering is the art and science of production that … is one of the most fundamental of human activities. … Modern engineering … amplifies traditional ingenuity by the power of scientific reasoning and knowledge. … It acts at the vortex, merging research and development … and industry and business"*

There are Australian examples, of course, of excellent engineering companies in niche areas of communications, manufacturing, biomedical products, as well as in minerals and material processing. The investment in CRCs and research is intended to produce high returns. Nevertheless, Australia does not appear to think of itself as an economy built on creative science, engineering and technological enterprise that writers such as Florida[81] describe to characterise future successful nations, cities and regions. Australia appears well placed, ranking 8th on the World Bank index[82] for having the infrastructure for knowledge-based economies, including education, and a strong industrial legacy. But many consulted in this study expressed concerns that this position will be lost unless there is renewed focus on higher future performance in generating, commercialising and exporting ideas in the form of high-valued engineered products and services. Promoting such ideas to the public will require long term engagement of all stakeholders, as proposed in Recommendation 1.

Australia does, however, celebrate and recognise scientific and medical research excellence. Many contributors to the study referred to the strong media coverage of science, and wished that engineering achievements could gain higher profile. There is some evidence that science writers subsume, rather than distinguish, the different roles that engineers have in innovation and problem solving.

Students referred to two popular television shows: *New Inventors*, often featuring engineers Dr James Bradfield Moody (see Box 2) and Professor Veena Sahajwalla (from the University of New South Wales) as panellists; and *Mythbusters* as having good engineering elements, even if the term engineering is rarely formally used in their scripts. Recent formal presentations of engineering on television, through the BBC series *Seven Wonders of the Industrial World*, and the ABC's *Constructing Australia*[83] featuring the Sydney Harbour Bridge, Kalgoorlie Pipeline and Overland Telegraph, were noted appreciatively as good presentations of the 'heroic era' of engineering, particularly by older academic and industry members. The contemporary issue is to find how best to use television and digital media to represent modern engineering and inspire future engineers.

Reflecting on the success that television shows featuring forensic science have had on student demand for university study in that area, many contributors pondered if a popular TV drama series could effectively showcase an engineer. Students, academics and industry contributors talked positively about a recent television promotion of the accounting profession (using an engineering plant as a backdrop), wishing that engineering could match its style. Clearly much of the general public's knowledge of medicine and the law comes from their saturation level exposure in television and film drama; neither profession needs to advertise for prospective students, directly or indirectly.

To promote engineering to the public and to school students effectively there is probably much more to be gained by focussing more on its generic engineering purposes – as valued outcomes – rather than on technological content. In doing so, engineering can be shown to be different from but complementary to science and technology, and also emphasise its symbiotic relationship with the business world, as in the following statement by Browne, in his role of President of the UK Royal Academy of Engineering[84]:

> *"Engineering is the practical means by which our greatest challenges will be solved, such as [sustaining] the environment, reducing poverty, and [increasing] health and wellbeing. We engineers are trained and practised at looking in two directions at once – both at science and at business and commerce – and integrating them to find an optimal solution. We bring a highly effective problem-solving approach to the challenges that come our way. Those who wish to make a difference to the world should, I suggest, become engineers."*

The language of this quote may be more positivist than some find comfortable, and most would agree that engineers alone will not solve these global problems; they must work with other professionals and communities to effect the desired outcomes. Nevertheless, it is a powerful statement that does point to the great opportunities that engineering offers to prospective students, and is likely to stimulate interest. The sentiments certainly resonate well with expressions of commitment to water, energy, new materials and health-related applications made by several students encountered in this study.

The symbiosis between engineering and business could also be enhanced further in Australian education, as has been indicated in section 7.6. An unusual perspective on this was encountered in one consultation, where a current engineering student who already had a business degree expressed his engineering motivation as: "*there are many much more interesting things to measure than dollars*". His stated career engineering interest was in renewable energy systems.

Many of the consultations discussed the professional body, Engineers Australia's prime responsibility to raise the profile and status of engineers. As a body based on voluntary membership, rather than on compulsory membership associated with licensing and registration roles, (see section 2.1), Engineers Australia is substantially different from other professional bodies. Nevertheless, Engineers Australia has actively supported numerous campaigns and initiatives to improve the position of engineering and engineers, and many of the initiatives proposed in Recommendation 1 of this report will be undertaken in partnership with Engineers Australia. It is clear, however, that the time pressure on many employed engineers in industry and in universities, and their decisions regarding work-life balance may restrict the total capacity of the profession to undertake volunteer work. A larger engineering workforce and correspondingly higher membership of the professional body would be advantageous to all.

9.2 Collaboration between engineering education and school education

As discussed in Chapter 6, the size of the pool of school students ideally qualified and motivated towards engineering has been roughly static for a decade. Engineering schools, and indeed science faculties and schools, have therefore engaged in numerous outreach activities to arrest any further declining trends, and if possible reverse them. Engineering schools believe they start at a disadvantage relative to their science and mathematics colleagues simply because the latter subjects form major school education learning areas, and engineering does not, at least in most Australian states. (Despite this disadvantage, engineering has been more successful than physical science and mathematics in maintaining numbers in higher education, due presumably to the professional career pathways that engineering offers.) The universities' faculties of education and their students working toward teacher education also rarely have direct engagement with engineering.

The desirability of providing school teachers with greater awareness of engineering was raised by several contributors to the study. Careers teachers, in particular, appear to lack the key information about the opportunities that engineering education offers, and the aptitudes that are needed for success in engineering (ref 14). The stress on engineering requiring "*being good at mathematics and science*" needs to be balanced with constructive support for sound development of good communication skills. Above all, the consultations revealed that conveying to schools a stronger emphasis on the broad outcomes and opportunities of engineering could better position engineering as a broad generic degree that could yield a positive response from more students, and especially women.

During the past decade engineering schools and the professional at large have been extremely active in developing school students' interests in engineering, through both in-curriculum and extra-curricular activities. In the latter category, the Science and Engineering Challenge[85] created at the University of Newcastle, the CSIRO Double Helix[86] programs, and the Siemens Summer Science Schools, and Engineers Australia's many outreach projects are well known across Australia. Most states and territories have science engagement activities. The Re-Engineering Australia [87]movement is making major contributions to improving understanding of engineering in primary and secondary schools.

A relatively new and effective strategy to engage school students in in-curriculum science, technology, mathematics and engineering (STEM) has been through student-peer mentoring. Several Australian universities have adopted this approach, with the

University of South Australia taking it further than most, particularly in engineering, as described in Box 11.

There is anecdotal evidence that these programs are now contributing directly to recruitment into university engineering programs, but there is scope for greater impact. Through these and other programs that for example, bring school classes onto campuses, school teachers are becoming more aware of engineering, and its relationships with science and mathematics. Generally speaking, engineering academics and industry members have been enthusiastic about strengthening the engineering content of secondary school studies.

One idea raised during the consultations was to resource systematic development of a repository of school-level curriculum examples from engineering that would assist teachers to motivate school students to excel in science and mathematics and encourage more to envisage their own futures in the STEM domains.

Box 11: Robotics Peer Mentoring at the University of South Australia (UniSA)

Inspired by the STAR program at Murdoch University, Robotics Peer Mentoring (RPM) started at UniSA with a conventional program of student-peer mentoring in secondary schools with low levels of attainment in mathematics and science. RPM took the concept further as an innovative program aimed at providing hands on experience in robotics, electronics, science and engineering for secondary school students.

The original RPM program linked UniSA undergraduate students as mentors with secondary teachers to deliver a robotics program which was both engaging and challenging for the school students. Guided by undergraduate University student mentors, secondary students and their teachers learned how to build and program a robotic vehicle.

From 2004 the program expanded with government support to involve the other SA universities and TAFE, and up to 1000 school students per year. The school students gain appreciation of the underpinning science and mathematics (now linked to school subject curriculum) of electronic applications and the importance of these key areas in the development of higher level engineering skills. Student and their teachers also have opportunities to experience how the technologies are used in industry and to develop a better understanding of career possibilities and the various education and training pathways available to achieve a range of employment outcomes in electronics and associated industries.

The undergraduate mentors take gain valuable communication, interpersonal and some technical skills through the activity.

The program won an Australian Engineering Excellence award AusIndustry award for innovation in 2003

Edited extracts from the Dean's submission on innovation

Many of the consultations discussed the possible introduction of a high status 'engineering' subject in the school curriculum. The current provision of such subjects differs between states and territories. University engineering students who had undertaken such subjects reported on their high content value in their subsequent engineering studies, yet the universities' engineering schools do not necessarily promote them or these benefits. Students pointed out that there are senior school certificate business subjects that pre-dispose students to think about business at university. Most engineering academic staff are inclined to favour the traditional entry expectations of mathematics and science, and are wary of further options that might reduce the numbers in those subjects, as might be the case with the introduction of an engineering subject. The issue deserves further consideration, perhaps with a focus on preparation more for the engineering technologist pathway. This idea could be also aligned with the emergence of the Australian Technical Colleges and more Vocational Education in schools, both of which need to be more strongly embraced by the higher education sector.

Mindful of the shortage, and not only in Australia, of science and mathematics teachers, several of the consultations discussed how engineering might assist. Having retired engineers in school classrooms, after suitable training, was suggested by some. Assisting fast-track education pathways for degree qualified engineers to gain full teacher qualifications could be attractive for some mid-career engineers. Since the universities are responsible for teacher education it would be relatively easy for engineering deans (and those covering science, mathematics, and information technology) to explore the value of collaboration with such fast-track programs in mind, and also to improve teacher education for the STEM area through closer connections between teacher education and engineering curricula.

One concern here is that the engineering and science professions tends to use the term 'technology' rather differently from its use in schools. There, technology usually, and narrowly, tends to refer specifically to information technology or the metal, wood and plastic forming crafts. To many engineers, 'technology' is more concerned with usefully packaged ***applicable scientific knowledge and tools*** in the forms of hardware and software devices, subsystems, products and services for particular fields of endeavour. Using the latter, higher-level, definition of technology across the whole of the education system could perhaps also assist to raise the level of understanding of the role of the engineering technologist.

10 Collaboration with industry

The *Changing the Culture* review urged greater collaboration between engineering schools and industry. While there has certainly been good collaboration over the decade in both research and education, the broad framework for collaboration has not changed substantially. Indeed, in Recommendation 5, the present project proposes similar actions to those of a decade ago. Collaboration between the engineering schools and industry evidently needs constant attention and nurturing by both set of stakeholders. The importance of exposure to engineering practice in undergraduate curricula was discussed in section 7.5 and Chapter 8 included some references to industry collaboration in areas around staffing and resources. This section of the report describes a number of successful collaborations that support engineering education, particularly in areas of high graduate demand, and provides evidence to support the proposed actions in Recommendation 5.

10.1 Industry advisory processes and their future roles

All engineering schools with accredited programs have instituted industry advisory mechanisms, as required by Engineers Australia, and indeed, by many universities themselves. The consultations undertaken in this study at many of the universities involved members of these industry advisory groups: the willingness of busy members of industry to get involved with engineering schools is highly noteworthy. In many instances, of course, their close industry engagement with the engineering schools allows more direct industry involvement with student projects, work placements and graduate recruitment. Some of those consulted also taught part-time, so had direct involvement with students' learning. The industry groups were particularly valuable with respect to assessment of graduates' attributes, as reported in Chapter 7.

One standout industry advisory group operates at the University of Technology Sydney, as described in Box 12. Its strengths are characterised by the high standing of its participants, its frequency of meetings, and task-orientation. Another very good example of industry support for the engineering curriculum and students in a regional setting is at the Gippsland Campus of Monash University.

Box 12: The Industry Advisory Network (IAN) at the University of Technology Sydney

The IAN advises the Faculty of Engineering on strategic issues, as well as undergraduate education. Its overarching goal is to maximise the alignment between the UTS engineering programs and the needs of Australian industry. IAN's membership includes senior executives (including at Board level) of major engineering companies, as well as the Faculty leadership team. IAN has monthly meetings, alternately face-to-face or by teleconference. Working parties have been established to investigate strategic issues.

The IAN sponsors breakfast forums and its Zunz lecture series, the latter presented by very eminent speakers from engineering and business, with invited audiences of around a hundred attending. IAN has also been involved with course reviews, and the Faculty's Scholarship forum.

Edited extracts from the Dean's submission on innovation and IAN Annual Report 2006

Many members of industry advisory groups acknowledge that academics have the expertise to design and implement sound curriculum: that is their special skill. On the other hand, engineering practice other than in research is what industry and business do, and it is this knowledge that industry advisors bring to the academic table. It was suggested that industry advisory groups could assist engineering schools to systematise their approaches to ensure greater authenticity in some aspects of the curriculum, and to ensure appropriate knowledge of contemporary engineering practice are provided in all program areas, including during students' industrial experience. Engineers Australia, as part of its accreditation management system, expects industry advisers to actively contribute to the specification, review and attainment monitoring of targeted graduate outcomes.

There is also potential, explored at the AaeE Conference university-industry workshop, to exploit the aggregated or national knowledge of the industry advisory groups. Their members could both learn from each other and work together to create a higher level support group to lobby government for higher levels of resources for engineering education.

Other areas discussed were at both strategic and operational levels. On research planning, many of the academic consultations raised the issue of promoting higher levels of research engagement with industry, such as stimulating opportunities for academic staff to work in industry, through mechanisms such as joint-appointments, on the principle that benefits accrue to both the partner organisation and the participating staff member. Examples of success in this area need to be promulgated widely to gain the confidence of academics and industry, as there is a perceived danger that joint-appointments can be very difficult for their holders to manage.

Other areas proposed for strategic development include:

- sector-wide strategic funding of 'industrial engineering fellowships' to support the practice elements in engineering education;
- establishment of a national strategy for laboratory equipment acquisition, operation and utilisation. The proponents of this initiative envisage establishing a specific endowment fund, primed by government and industry, in return for tax incentives, administered by a consortium of industry and professional representatives, such as ACED, AaeE, Engineers Australia, and peak bodies associated with relevant engineering industry sectors. The model would aim to ensure Australia has leading edge laboratory facilities in engineering available to students and industry.

Further industry support for more students to progress in their engineering studies without major financial burdens was also discussed. Many would want to build on the successes of IBL programs and co-operative models that include good quality industry experience, and make such programs available to a much higher proportion of engineering students.

10.2 Industry-driven initiatives in areas of high graduate demand

There are several reasons why undergraduate engineering education does not operate as a market system, with student demand directly following that for graduates. One is the restricted nature of the pool of prospective students, discussed in section 6.2. A second factor is the long time – typically 5 or 6 years – between making a decision to study a particular branch of engineering and graduating. Engineering areas reputed to have declining or cyclical employment patterns may be further disincentives.

Within an engineering school, a major decline in student demand for a discipline area sets in train the inevitable processes of resource reduction as it loses financial viability. The late 1990s saw reductions in student and graduate interest in electrical power engineering due partly to lower recruitment levels of engineering graduates in that industry and the information technology boom. The minerals resources sector, which is strongly cyclical, also suffered a decline in student demand. The academic capacity in the declining areas was wound down. Although it may take 3 or 4 years to actually close an engineering area, as remaining students complete their programs, creating new high-quality schools and reviving engineering areas takes major investment. A university will embark on such investment only if the activity is likely to be sustainable over a decade or more. In areas of high graduate demand, industry-driven initiatives can provide engineering schools with both resources and confidence to revival and growth of academic capacity. The industry support also has direct advantages for students, including scholarship and placements, as well as high likelihood of graduate employment.

Box 13: Minerals Tertiary Education Council (MTEC) and Mining Engineering Australia (MEA)

MTEC was formed in 1999 to build a world-class tertiary learning environment for the education of professionals for the Australian minerals industry. Funds were allocated over five years to the development of course materials and the employment of academic staff in consortia of universities and centres in the areas of earth science, mining engineering and metallurgy. Currently the program is providing geoscience and metallurgy short courses at undergraduate and postgraduate levels.

Mining Education Australia commenced operation in 2007 as one program and one school delivering world-class undergraduate education in mining engineering. Supported by MCA as national collaborative education joint venture between the three major mining education providers in Australia; Curtin University of Technology (WA School of Mines), The University of New South Wales and The University of Queensland. Other universities may become Associate Members, giving their students access to the program.

MEA provides a common curriculum for 3rd and 4th year courses. The program will rationalise and improve teaching of mining engineering by coordinating resources to create a sustainable environment for the teaching of mining engineering.

The program is intended to attract and develop high quality students into mining engineering and develop them as graduates and researchers to the benefit of the mining industry and the Australian economy and society.

MEA is a world first in undergraduate mining education.

Edited extracts from the MTEC and MEA websites, http://www.minerals.org.au/mtec and http://www.mea.edu.au/ and information provided by the MEA Executive Director

In both the minerals and electrical power sectors, industry consortia have formed to support graduate numbers growth. Inter-state consortia can exploit the best academic capabilities available, rationalise contributions from across the sector and provide programs more efficiently for a wider student catchment. The looming critical shortage of graduate engineers for the mineral resources sector became apparent to the industry in the late 1990s. In many universities, metallurgical and mining engineering, minerals processing, and geology were struggling to recruit students, and several schools and departments were closed or closing. The Minerals Council of Australia took action to support the industry, most recently forming 'Mining Engineering Australia' from the three largest engineering schools to develop programs in collaboration and support prospective students, see Box 13. Since its original inception, other universities have joined MEA.

The rationale, formation and aims of the Australian Power Institute, to address the shortage of graduates for the power industry, are described in Box 14. During 2007-2008 the institute is funding student bursaries and support to attract women into engineering, course development, including on-line modules to be made available nationwide and short-courses, academic teaching positions, and research.

Box 14: The Australian Power Institute

The Australian Power Institute (API) is a not for profit national organization established by the electricity power industry to boost the quality and numbers of power engineering graduates with the skills and motivation for a career in the energy industry.

Recent research estimated that there are currently approximately 5000 power engineering professionals in the industry and it is forecast that 700-1000 additional graduates will be needed in the next 5 years to meet growth and retirements from the industry.

Our vision is to create "sustainability and excellence in Australia's power engineering". The key objectives of API are to achieve the following:

- attract students to consider power engineering as an exciting whole of life career choice.
- facilitate world class undergraduate power engineering courses and academic resources available to students.
- provide value adding post graduate development and applied research to industry.
- position API as a vibrant, well respected organization by key stakeholders ie industry, universities and government.

During 2007-8 the institute is working with the University of Technology, Sydney, Curtin University of Technology, the University of Tasmania, Queensland University of Technology, University of Queensland and Central Queensland University (via the Power Engineering Alliance, Queensland), and Victoria University.

Edited extracts from the API website, http://api.edu.au/

The third example of an industry-led initiative illustrates how an industry sector, in this case, electronics manufacturing, has worked with local universities to ensure that students have access to specialised high level courses, and graduates can be assisted to transition into employment. The South Australian electronics industry is characterised by small and medium sized enterprises producing high-value products, mostly for export. The Electronics Industry Education Initiative (ei)^2 developed from discussions between electronics engineering program leaders of the three SA engineering schools and industry leaders around the concept of making advanced undergraduate courses available to students for all three universities (see Box 15). Although this option is reportedly not taken up by many students because of the inconvenience of inter-university travelling, the program has developed a number of initiatives to encourage school students into electronics engineering (contributing to the schools-outreach activities discussed in Chapter 9) and to assist university and VET students to make effective transition into the workplace.

These three examples serve to show both how industry initiatives can work with the engineering schools, usually collaboratively to meet education needs. The intervention and support of industry provides the incentive to the universities to collaborate in rational and effective ways, an important principle of success referred to in the reflections on the *Changing the Culture* review in section 3.3.

Box 15: Electronics Industry Education Initiative $(ei)^2$:

The South Australian Electronics Industry Association and SA Government have supported this initiative as a free service to service to support growth of the electronics industry. The initiative is aimed at attracting and retaining young people to electronics, as well as supporting their career development.

The $(ei)^2$ is about linking education with industry. The services provided assist electronics students to have a better set of skills, gain work experience, and become more job ready for when their studies are finished.

The key programs provided by $(ei)^2$ include university shared courses, career mentoring, assistance with work experience, internships, professional development courses, and career events.

Edited extracts from the EIA website: http://www.eiaa.asn.au

11 Recommendations for Action

Recommendations and actions were developed, considered and revised by the Steering Committee during September – November 2007. At its meeting on 13th December ACED considered them in detail, endorsed them, and suggested further amendments, as included here.

Each of the recommendations has identified 'responsible organisations', 'other stakeholder organisations that may potentially contribute to the actions, and 'measures and milestones' that may be used over time to track the success of the implementation of the proposed actions. Each of the actions has an identified leader.

The recommendations are intended to be a 'roadmap' for the next decade of development of Australia's engineering education system. To provide leadership of the implementation of these recommendations, maintaining the momentum of the study and commitment of the stakeholders, the Steering Committee proposes that an Implementation Team be led by ACED and operated under the Tripartite Agreement. This team will champion and provide strategic leadership of the implementation of the recommendations, chart their progress, and report at least annually to ACED, Engineers Australia and ATSE.

Recommendation 1: the public perception of engineering

Raise the public perception of engineering, including within primary and secondary schools, by increasing the visibility of the innovative and creative nature of engineering and the range of engineering occupations that contribute to Australia's prosperity, security, health and environment.

Responsible Organizations: Engineers Australia, working with ATSE and ACED as an activity of the Tripartite Agreement, and with strong industry input.

Other Stakeholder Organizations: APESMA, ACEA, AAEE, BHERT, BCA, TAFE/VET; engineering businesses; government departments who own and operate engineering infrastructure; and the school education sector.

Measures and Milestones: (to be monitored under the Tripartite Agreement): for each of the following, the primary action leader is to set timelines and target figures and provide periodic reports on the process and achieved outcomes. The frequency and content of such reports are to be determined in consultation with the other responsible organizations and stakeholders.

(a) Promotion of engineering:

- increasing depth and accuracy of public perceptions of engineering and engineering occupations as measured in market surveys of general public and school students
- increasing positive media coverage of Australia's engineering enterprises and prominent engineers
- increased coordination of schools outreach activities in engineering

(b) Recruitment of students

- increasing proportion of the most able school students choosing engineering for tertiary study

- increasing numbers of mature entrants into engineering education, including re-entry pathways
- increasing engineering content in school education, including in mathematics and science
- increasing engineering content available in teacher education programs

Proposed Actions:

The proposed activities will be undertaken as collaborative partnerships, and integrated to build cohesively and substantially on the many activities already being undertaken, within minimum duplication of effort to maximise the outcomes of the resources available.

i) Convene high-level stakeholder forums to achieve engagement with this recommendation area, refine 'the message', and commission market research on the public perceptions of engineering and the work of engineers at each of the established occupational levels. (An underlying objective of future actions would be that membership of the professional engineering body would be perceived as equivalent to that of the Australian Medical Association for medical practitioners.)

Action leader: Engineers Australia

ii) Commission research to model the economic contributions and the risks of further decline of engineering education (at all levels) to Australia, and argue with government for differential funding model to restore staffing and laboratories to internationally competitive levels.

Action leader: ACED

iii) Engage the media at a high-level, to improve the accuracy of reporting on engineering, including wider exposure of national leaders in engineering or with engineering education, such as those identified in Engineers' Australia's '100 Most Influential Engineers', 'Women Engineers' and 'Young Engineers'.

Action leader: Engineers Australia

iv) Promote engineering education in universities more strongly by emphasising its contributions to society, outcome attributes and career and lifestyle opportunities, using case studies as well as some of the above initiatives, and stressing the human dimensions and the career pathways of highly successful young engineers and alumni. Emphasise the generic and enabling characteristics of engineering education.

Action leader: ACED and ACED members

v) Form consortia of engineering schools, industry and the school education sector to develop contemporary engineering examples to support school-level mathematics, science and technology subjects. Develop short courses on engineering for school educators in mathematics, science and technology, and also for school careers advisors.

Action leader: ACED

vi) Commission a nationwide study of school curricula to ensure that all states and territories have contemporary engineering subjects at senior levels to underpin increases in numbers of school students taking engineering at tertiary level. These subjects should stress creative design, systems and technological aspects of engineering and its broad context, and be preferred subjects for university admission to engineering.

Action leader: ACED

vii) Engineers in universities, industry and the profession must take a stronger lead in initiating and developing partnerships and outreach to the school education sector. This could be supported by a national repository of information about schools' science and engineering engagement and outreach schemes, to assist all stakeholders to increase the impact of their work and reduce duplication of effort.

Action leader: Engineers Australia with ACED

viii) Develop partnerships between engineering and education faculties at selected universities to facilitate the inclusion of engineering content in undergraduate and post-graduate teacher education programs and also to enable cross faculty teaching input to both engineering and teacher education at university level.

Action leader: self-selected ACED members

Recommendation 2: the engineering occupational levels and graduate outcome standards

Develop, support and promote the concept, reality and importance of all members of the engineering team – Professional Engineers, Engineers Technologists and Engineering Officers – in the successful implementation of engineering work. Review the graduate competencies and reference standards for the qualifications for each level.

Responsible Organizations: Engineers Australia and ACED

Other Stakeholder Organizations: TAFE/VET, ATSE, AaeE

Measures and Milestones: Engineers Australia, as the primary organization responsible for implementing this recommendation, should set timelines for the development and review of the following. The timelines should include short- and long-term targets, including those to be addressed during the preparation of grant proposals:

(a) Standards and qualifications:

- revised graduate outcome standards and competency statements that meet current and future industry needs
- revised education program and qualification frameworks that meet required standards and can increase student demand for study at all qualification levels

(b) International standing

- increasing Australia's international position as a provider of high quality engineering education, and maintaining Australia's strong position within the International Engineering Alliance (Washington, Sydney and Dublin Accords)

(c) Student enrolments and throughput:

- ensuring sustainability of supply of high quality entrants into all levels of the engineering workforce that meet occupational needs
- increasing the overall throughput of students and graduates through the education system by providing clear and effective education programs with articulation pathways and professional development support

Proposed Actions:

i) Commission research on current and emerging occupational needs to support a review of Stage 1 competency standards and graduate outcomes for each of three internationally recognised occupational levels of the engineering team. Clarify the education and workplace expertise that is needed to progress between qualification levels.

Action leader: Engineers Australia and ACED

ii) Review the Australian qualifications, graduate competencies, reference standards, and registration requirements for the three engineering occupational levels and promote these within industry, the community and educational institutions the concept, reality and importance of each of these occupational levels underpinning the Australian engineering workforce.

Action leader: Engineers Australia and ACED

iii) Revise the current accreditation standards for education programs leading to the attainment of Stage 1 competencies for each of the three occupational categories defined for the engineering team, and address specifically issues of innovation and complexity in professional engineering. Ensure that these proposals include recognition (in a suitable manner) of stand-alone masters degrees in engineering, engineering science, and engineering practice.

Action leaders: Engineers Australia and AaeE

iv) Argue for enhanced government support for rapid development of programs and curricula to meet the new standards at each level, taking into account the range of school-leaver knowledge and skills in mathematics, science and English.

Action leaders: Engineers Australia and ATSE

v) Commission a study of the educational, personal and aspirational attributes of students commencing engineering awards at all levels, including masters. The study will include a specific focus on students in double/dual/combined degrees in engineering and their initial (5 year) careers as graduates.

Action leader: ACED

vi) Argue for enhanced government support for rapid development and deployment of postgraduate engineering conversion courses programs and curricula to address the shortage of professional engineers.

Action leaders: ACED, Engineers Australia and ATSE

Recommendation 3: implementing best-practice engineering education

Engineering schools must develop best-practice engineering education, promote student learning and deliver intended graduate outcomes. Curriculum will be based on sound pedagogy, embrace concepts of inclusivity and be adaptable to new technologies and inter-disciplinary areas.

Responsible Organizations: ACED and AaeE

Measures and Milestones: the leaders of this recommendation should collect further data about the current status of education practice, as a baseline for gauging progress towards achieving the set milestones. They should set criteria for assessing progress, and devise processes for reporting and monitoring on outcomes that include expectations of:

- increasing employer satisfaction with engineering graduates, as measured by suitable sample surveys

- increasing graduate satisfaction with educational experiences and transitions to employment, as measured by GCEQ and suitable survey instruments
- systematic and holistic educational design practices with learning experiences and assessment strategies that focus on delivery of designated graduate outcomes
- increasing dissemination and sharing of development effort, best-practice course design, packaged learning resources and other courseware across engineering schools
- quality systems which rigorously close the loop on delivery of graduate outcomes
- increasing recognition of pedagogically sound, innovative and inclusive curricula
- increasing recognition and empowerment of engineering educators within universities
- increasing attractiveness of Australian engineering schools for international partnerships and student and staff exchanges
- increasing attractiveness of engineering to talented students and women

Proposed Actions:

This area will form the core of ACED's future proposals for funding from the Australian Learning and Teaching Council , through project proposals. ACED has the expectation that its members should endorse curriculum innovation undertaken locally and in consortia of similarly minded institutions, in program discipline areas, and thematic areas, building on examples of best known work. Over time, a more common set of approaches, with local differentiation, may be the most desired outcomes. ACED will need to establish processes and metrics to actively support and monitor activities and outcomes. Some of the issues listed below will have different expression and implementation for each of the three levels of engineering award. Projects are envisaged that:

- disseminate pedagogically-sound and inclusive excellent educational design and practice developed nationally and internationally in engineering schools in recent years
- promote and implement systematic and holistic educational design and review approaches that track aggregated delivery of designated graduate outcomes through individual learning experiences and assessment processes
- examine the development and deployment of a professional engineering curriculum to be operated by consortia of engineering schools, based on a systems oriented common two-year core, followed by sub-discipline specialisation at the partner schools
- define and implement inclusive curriculum for engineering: reducing male stereotypes within the curriculum, and revitalising the best of the *Women in Engineering* programs (also Recommendation 6)
- develop understanding of the diversity of learning styles of commencing students, and the student work-life balance, and their impact on engineering curriculum (also Recommendation 2). This work has commenced through the Carrick Associate Fellowship's work 'Bridging the gap: matching students and staff through discipline-based self-evaluation and co-creation of more appropriate pedagogies in Engineering', to address aspects of students' learning styles and staff teaching styles.
- define curricula more strongly around engineering problem solving, engineering application and practice, and develop the themes of design, model-and network-centric engineering, the engineering life-cycle, complex systems, project management, global workflow, and multidisciplinarity

- develop stronger collaborations with mathematics and science departments to support improvements in the engineering education, and to contribute to the common interests of science, technology, engineering and mathematics (STEM) education
- implement engineering application activities that address contemporary issues and human dimensions, such as sustainability, environmental impact, risk, and social, business, legal, and economic factors
- internationalise engineering curricula and learning experiences
- reduce attrition rates from critical courses (without compromising outcome standards), using contemporary education theory, such as 'threshold' learning
- improve assessment practices, including peer-and self-assessment, and that minimise cheating, copying and plagiarism
- improve collaborative work and problem based learning, for example through the adoption of the CDIO framework, and introducing multi-disciplinary group projects at senior levels
- increase the authenticity of laboratory work and integrating more industry on-site experiences into courses
- improve the quality and intensity of industry-based learning
- define and implement appropriate business and management studies in engineering education
- commission evaluative surveys on relevant matters
- learn from other professional disciplines, such as architecture, law and medicine
- support associated staff development (Recommendation 4)

Recommendation 4: resources for engineering education

Enhance staff and material resources to enable delivery of engineering education that is demonstrably aligned with Australia's needs and compliant with international standards.

Responsible Organizations: ACED

Other Stakeholder Organizations: AaeE, universities, Engineers Australia, ATSE, BCA, governments (Commonwealth & State – MCEETYA), business leaders

Measures and Milestones: in the following, the organization with primary responsibility should provide target figures and timelines. Periodic reporting should also be provided during grant proposal development. There is some overlap with the metrics proposed in Recommendation 3.

- increasing take-up of academic positions by candidates with substantial and relevant industry experience
- increased number of engineering academics with formal educational qualifications
- adopting strategies aimed at increasing recruitment of women engineers in engineering schools, particularly at and to senior levels (also in Recommendation 6)

- increased networking and sharing of best-practice learning design, courseware, laboratory activity and specialist resources, and other learning resources
- increased networking of acknowledged expertise in engineering education
- increased take-up of industry-based study leave opportunities
- increasing funding per enrolled engineering student
- increased sharing of resources between research and teaching
- increased utilisation of technological tools for enhanced access, support and enrichment of learning, and to facilitate a more unified educational design effort
- increasing take-up of engineering research degree candidature by Australian graduates
- increased cooperation between all education sectors and industry, and greater cooperation between undergraduate and masters students

Proposed Actions:

i) Facilitate discipline-wide approaches for more effective and systematic sharing of educational design, common courseware, learning resources and laboratory facilities for both underpinning foundation studies as well as high level specialist courses. Implementations should also build on the ACEN network project and Carrick Exchange.

Action leader: ACED

ii) Develop and promote to government and industry the concept of a national strategy and endowment fund for laboratory equipment acquisition, operation and utilisation to ensure engineering education has access to best-practice engineering laboratories and learning spaces.

Action leader: Engineers Australia with the Tripartite Agreement

iii) Initiate discipline-wide discussions on frameworks for more effective and systematic sharing of best-practice support systems and staff deployment to maximise educational outcomes, for managing increased levels of student interaction and reporting, taking advantage of national funding schemes, such as CASR.

Action leader: ACED

iv) Promote to government and industry the need for specific additional funding and incentive support for higher degree research students in engineering, to nurture their progress, as professionals, some towards prospective academic careers.

Action leader: ACED with the Tripartite Agreement

v) Develop system-wide recruitment strategies and incentives to increase the supply of engineering academics, and particularly to support women to progress to senior positions.

Action leader: ACED

vi) Conduct workshops and forums for disseminating good engineering education practice in around emerging critical topics. (For example, take the annual AaeE national awards to a higher level, by having winners lead events.)

Action leaders: AaeE

vii) Investigate the merits of discipline-wide support for a national centre for engineering education that could become a leading provider of higher degree research in engineering education (including by distance delivery), and related coursework awards and professional development. Any such centre would be expected to link with the proposed Carrick DBI network covering science, engineering, mathematics, and IT.

Action leader: ACED

viii) Support (more strongly) academic staff to spend study-leave and other professional time in deep engagement with industry practice and have these outcomes accounted within university promotion processes where they are underpin improving curriculum in respect of improving students' engagement with engineering practice (see also Recommendation 5).

Action leader: ACED

Recommendation 5: engagement with industry

Engineering educators and industry practitioners must engage more intensively to strengthen the authenticity of engineering students' education.

Responsible Organizations: Engineers Australia, with ACED endorsement and monitoring of local, often industry-led initiatives

Other Stakeholder Organizations: ACED members with industry and business partners, including BCA and BHERT

Measures and Milestones: in the following, the organization with primary responsibility should provide target figures and timelines. Process and outcomes should be identified and frequency and content of reporting on progress should be set.

- more effective and increasing input from industry practitioners to engineering schools in the processes of setting, reviewing and tracking attainment of graduate outcomes
- increasing quantum and quality of formal industry experience within engineering programs
- increasing evidence of exposure to professional engineering practice as an integral and substantive component of systematic educational design
- increasing number of joint university-industry appointments
- increasing number and value of industry-sponsored laboratories
- increasing number of industry-sponsored programs and short courses
- increasing academic staff experience of current industry practice
- increasing industry-supported scholarships for undergraduates and postgraduates
- increasing involvement of industry practitioners in teaching delivery

Proposed Actions – to be led by specialist industry groups and engineering deans and engineering program leaders in each university

i) Develop stronger and multi-institution industry advisory networks with sufficient stature to facilitate investment and commitment to educational improvements across the sector. The network could also be a lobbying force for increasing the profile and stature of engineering education as well as improving access to educational resources. Learn from other discipline areas, such as medicine and law where close cooperation between academics and industry is almost taken for granted.

ii) Set standards of industry engagement that are compatible with program vision and focus as well as a holistic educational design process (including engineering research). Ensure that standards embrace industry-based work-experience programs and other methods of exposure to professional practice that underpin an integrated and holistic educational design process that assures delivery of designated graduate outcomes.

iii) Build a more systematic and unified approach to industry engagement across the sector, with partnerships that are built on the principle of mutual benefit.

iv) Develop models and strategies for industry-sponsored scholarship schemes that will facilitate demand for places in engineering education, satisfy short and medium term skills needs and contribute to the delivery of quality graduate outcomes at each of the occupational levels.

v) Encourage and support academic staff to undertake collaborative research on engineering practice, with full recognition of outcomes that improve students' engagement practice. Best practice outcomes should also be reported in engineering education literature and forums.

vi) Encourage more university-industry joint academic appointments (at all academic levels), with adequate support by each partner to ensure maximum mutual benefits into engineering practice curriculum, as well as research and innovation.

vii) Increase the authenticity of students' educational experience with, for example, sponsored individual and group project work, joint laboratory development, programmed site-visits and high quality guest lectures on matters of contemporary engineering practice, industry led case studies and direct student engagement with practicing professionals, some under the auspices of funded 'industry fellowship' schemes.

viii) Increase the number and value of scholarships available to undergraduate and postgraduate students.

ix) Develop specialist engineering postgraduate programs and courses tailored to the needs of specific industry sectors (power, roads, transport, aviation, microelectronics, defence, water, etc.)

Recommendation 6: address shortages by increasing diversity in engineering workplaces supported by engineering education programs

Address shortages in the engineering workforce by attracting and retraining people from non-traditional backgrounds e.g. women, mature age engineers, engineers with overseas qualifications, engineers who have left the profession, and engineers wishing to articulate between qualification levels. Ensure the future needs of employers are matched by the number and types of programs on offer.

Responsible Organizations: ACED

Other Stakeholder Organizations: AaeE, Engineers Australia, ATSE, and industry and business partners

Measures and Milestones: increasing proportion and number of women undertaking engineering education, for all occupational categories

- increase opportunities for women engineers to maintain and upgrade their education

- increase in number of women engineering academics
- development of appropriate bridging courses
- increase number of overseas qualified engineers in the workforce

Proposed Actions:

In the following, the organization with primary responsibility should provide target figures and timelines. Process and outcomes should be identified and frequency and content of reporting on progress should be set.

i) Work with the Office for Women (and related agencies in the States) and Engineers Australia's National Committee for Women in Engineering to identify the major barriers to higher participation of women in engineering education, and reinstate and reinvigorate Women in Engineering programs within engineering schools.

Action leader: ACED

ii) In collaboration with employers, research the needs for educational support for women seeking to re-enter engineering practice after child-rearing, or seeking to maintain currency while in part-time employment.

Action leader: ACED

iii) Develop, with government, incentives to encourage women engineers to develop careers in engineering education.

Action leader: ACED

iv) Develop, with government and industry, incentives, including suitable bridging programs, support and opportunities to encourage engineers and others with motivation from non-traditional educational backgrounds (overseas qualifications, science degrees, VET, lack of pre-requisites) to enter and re-enter the profession, on fast-track accredited educational pathways.

Action leader: ACED and Engineers Australia

12 Postscript

The stakeholders to the project funded by the Australian Learning and Teaching Council intended at the outset that this review and recommendations would set the directions for further research, stakeholder collaboration, and curriculum developments in Australian engineering education. Communicating the findings and recommendations has therefore been a high priority.

The author has presented the review process and findings at several national and international conferences, and other meetings (see Appendix 9). The findings of the project have also been used as evidence for ACED's submissions to the Commonwealth government reviews on the National Innovation System and Higher Education, and the Parliamentary Inquiry into Research Training and Research Workforce Issues in Australian Universities. This revised version of the original report to ALTC, and its summary, are intended to assist the stakeholder community to frame and collaborate on relevant development and research work.

Several new projects that pick up on one of more of these recommendations have been proposed by members of the engineering schools to the Australian Learning and Teaching Council for funding. Those that have won funding support include:

- *Design based curriculum reform within engineering education*, led by Dr Carl Reidsema, University of New South Wales, with the University of Melbourne, Queensland University of Technology, and The University of Sydney. This project has been awarded $220,000 over two years. It will focus on the development of engineering design-centric curricula based on sound pedagogical principles and also aims to build a community of practitioners to lead curriculum change.
- *Gender Inclusive Curriculum in Engineering and Construction Management*, led by Associate Professor Julie Mills from the University of South Australia, with the University of Newcastle, University of Melbourne and University of Technology Sydney. This project has received $190,000 over two years. The purpose of the project is to bring about sustainable change in teaching in engineering and construction management that will contribute to increasing the participation of women.
- *Curriculum Specification and Support Systems for Engineering Education that Address Revised Qualification Standards,* led by the author of the present report with the University of Technology Sydney, and the University of South Australia, The University of Queensland, Central Queensland University, The University of Melbourne, Engineers Australia, AaeE and ACED. Potentially the project will involve all 32 engineering schools. This project has received $219,000 over two years and covers four themes: attrition from engineering programs, development and trial of a postgraduate course unit in engineering pedagogy for engineering academics, revision of the specifications and qualification standards for all three levels of engineering awards, and development of educational support for to widen entry into engineering.

The Executives of ACED and AaeE, together with Engineers Australia and the Academy of Technological Sciences and Engineering remain committed to the objectives of the review, as well as to their ongoing initiatives that intersect with them.

13 Acknowledgements

The author acknowledges: Professor Archie Johnston for facilitating administrative support and an office at of the University of Technology Sydney, and for his initial championing and leadership of the review project; the major contributions to the project by Emeritus Professor Alan Bradley, Associate Director, Accreditation, Engineers Australia, in facilitating several of the focus groups, and assisting with the preparation of the project report; the support of the Australian Council of Engineering Deans, and in particular Professors Elizabeth Taylor, Archie Johnston, and Peter Dowd during the course of the project, and subsequently.

The author also acknowledges: the contributions of all members of the Steering Committee, and its chair, Professor Mary O'Kane in particular, for their advice and support throughout the course of the project;; and Emeritus Professor John Simmons, who as Executive Officer ACED, developed the initial project proposal in 2006 and provided support of the project during 2007.

The project would not have been conducted without the financial support of the Australian Learning and Teaching Council. The whole engineering education and professional community is indebted to ALTC for providing the project funding.

Appendix 1 The ACED review proposal: summary of issues

Extract from the successful project proposal for Carrick Institute funding, November 2006

Project Leader: Professor Archie Johnston, Dean of Engineering, University of Technology Sydney, and President of ACED, 2005-6

Aims

To ensure that the engineering education sector across Australia's universities produces in a sustainable manner, a diverse supply of graduates with the appropriate attributes for professional practice and international relevance in the rapidly changing, competitive context of engineering in the 21st Century.

Goals

Over the last year ACED has identified many important issues associated with engineering education in Australia that must be addressed, including the following:

a) The effectiveness of the 1996 national review of engineering education on 'changing the culture' of Australian engineering education, and the organisational structure and culture within engineering schools;

b) The impacts of the declining high school preparation in the enabling sciences and mathematics, and rapidly developing new technologies, on engineering course structure, standards and duration;

c) The impact of globalisation and recent overseas reviews on Australian engineering education, including the impact of Bologna protocols, on the export of engineering educational services and the international transportability of Australian qualifications;

d) The value of engineering education as an enabler to different career options;

e) The gender balance in engineering education and practice and how it might be improved;

f) Industry-university partnerships and how they are best developed to produce tangible benefits for all partners in engineering education;

g) Laboratory facilities in the schools of engineering: provision, updating and maintenance;

h) Development of an inquisitive and innovative culture in engineering graduates;

i) The place of a research-active environment, including engineering education research, in engineering education;

j) The effectiveness of instilling appreciation of social responsibility and sustainability as core graduate outcomes; and

k) The potential for significantly increased rationalisation of resources among engineering schools.

Clearly all of this list cannot be addressed satisfactorily in a one-year project with limited funding and sharp focusing will be needed. At its December Council meeting ACED will determine a set of priority goals for in-depth attention and other goals that will be addressed by way of proposals for further support. It is important that the focus and priorities be determined at a full meeting of the Council.

Project Team:

The Australian Council of Engineering Deans (ACED) leads the promotion and advancement of engineering education, research and scholarship on behalf of Australian universities. It works with engineering staff and students in all Australian Universities and dialogues with government, the community and industry on how best to serve their various needs.

Appendix 2 Project stakeholders

The Australian Council of Engineering Deans (ACED)

ACED is an unincorporated association of the leaders of Australia's engineering schools. Currently the following 32 universities provide accredited or provisionally accredited engineering degree programs engineering programs.

The Australian National University	Monash University	University of Queensland
Central Queensland University	Murdoch University	University of Sydney
Charles Darwin University	RMIT University	University of South Australia
Curtin University of Technology	Queensland University of Technology	University of Southern Queensland
Deakin University	Swinburne University of Technology	University of Tasmania (now inc. the Australian Maritime College)
Edith Cowan University	University of Adelaide	University of Technology Sydney
Flinders University	University of Ballarat	University of Western Australia
Griffith University	University of Melbourne	University of Western Sydney
James Cook University	University of Newcastle	Victoria University
Latrobe University	University of New South Wales	Wollongong University
Macquarie University	Australian Defence Force Academy (UNSW)	

ACED was responsible for the conception, oversight and delivery of the study. Three senior members of the ACED Executive served on the project Steering Committee (Appendix 3). The project was on the agenda of ACED meetings from December 2006 – April 2008. The deans were intrinsic to implementing the project methodology.

Engineers Australia

Australia's professional and accrediting body contributed considerable effort to the study, providing access to boards, committees and the general membership by publishing the requests for submissions. Emeritus Professor Alan Bradley, Associate Director, Accreditation served on the Steering Committee and facilitated four of the university consultations. His office also assisted in project liaison with Engineers Australia boards, committees and membership, and publishing the requests for submissions.

The Australasian Association for Engineering Education (AaeE)

AaeE is a Technical Society of Engineers Australia for the all university academics involved in engineering education. In collaboration with Engineers Australia, AaeE hosted an industry-university workshop at its 2007 conference to focus on key questions in the study. The AaeE President for 2007, Professor Wageeh Boles, served on the Steering Committee.

The Academy of Technological Sciences and Engineering (ATSE)

As one of the sponsors pf the 1996 review, ATSE was been keenly interested in the progress and outcomes of the present project. ATSE was represented on the Steering Committee by Dr Alan Finkel. ATSE invited the project team to publish an article[88]on the project in its issue on science, technology and engineering education.

Appendix 3 Project Steering Committee

Membership:

Emeritus Professor Mary O'Kane, FTSE, Chair
Professor Elizabeth Taylor AO, President, ACED
Professor Archie Johnston, Immediate Past President, ACED
Professor Peter Dowd, FTSE, Deputy President, ACED
Associate Professor Wageeh Boles, President, AAEE
Dr Alan Finkel, FTSE, ATSE nominee
Professor Phil Broadbridge, AMSI (leader of the Mathematics for 21C Engineers project)
Emeritus Professor Alan Bradley, Engineers Australia
Emeritus Prof Robin King, Project Officer/Manager

Terms of Reference:

The Steering Committee is responsible to the stakeholders (ACED, ATSE, AaeE and Engineers Australia) to deliver the Report and Recommendations (as above) and meet the required milestones of the Carrick funding.
The Steering Committee will:

a) provide active project leadership and overall guidance to the Project Team, *and*
b) facilitate access to sources of relevant quantitative data and qualitative information
c) facilitate high-level access to key stakeholders and influencers in government and industry, including with representatives of professional bodies such as ACS
d) provide commentary and feedback to the Project Team on the working papers and draft Report
e) advise on the key issues, recommendations and priority areas for subsequent Carrick project proposals
f) provide feedback to the stakeholders and conduits for advice from the stakeholders to the Project Team
g) authorize allocation of resources to the project (up to a certain level this may be delegated to President of ACED).

The Steering Committee will meet in April, August and November (to be confirmed). The ACED Executive will maintain a watching brief on the progress of the project between Steering Committee meetings. The Steering Committee may also establish Working Groups to assist the Project Team on specific areas of critical importance.

Meetings:

The Steering Committee met on 11th April, 12th June, 1st November, 26th November 2007, and 14th February 2008, at University of Technology Sydney.

Professor Trevor Evans, Chief Executive ATSE attended the 1st November meeting in the absence of the ATSE representative. Professor John Simmons, Executive Officer ACED attended on 1st November and 26th November in the absence of the ACED President.

Appendix 4 Focus group question sets

The facilitator commenced each focus group consultation with a short powerpoint presentation to explain the background and purpose of the study. Then each of the 'head' questions (1 – 9) was displayed to initiate discussion, supported by the sets of 'trigger' questions (i – vii) in the lists below). Most of the consultations took between 50 and 90 minutes. Time did not usually permit exploration of all questions during every consultation. The same question framework was used for all groups, with a degree of variation between Set A used for industry/academic groups, and Set B, used student/early year graduate groups. The discussion was recorded by the facilitator. A small number of the focus groups were supported by a note taker. The facilitator transcribed the discussions.

A. Industry and academic consultations. The Engineers Australia College Board consultations added the words 'in your sub-discipline' to provide focus.

1. <u>Graduate Demand:</u> To what extent does your business or area of activity (academics asked if industry is indicating shortages by demanding new programs) currently experience shortages of numbers of engineering graduates, including:

    4-year B.Eng ➜ professional engineers;

    3-year B.Tech or equiv ➜ engineering technologist

    2-year Associate Degree ➜ engineering officer/ associate
    postgraduate coursework and research

In what areas do you anticipate that there may be future critical shortages of engineers?

<u>(Academics were asked to respond to this question in terms of demand that industry is articulating to them.)</u>

i. B.Eng. – professional engineering shortages – eg mining and minerals processing, energy, emerging 'sustainability' industries, manufacturing, systems/defence engineering, ICT (eg software engineering)
ii. What future roles do you see for 2- and 3-year educated engineers (engineering technologists and engineering officers); to what extent are you employing B.Eng. graduates in technologist roles (including management)?
iii. Do you need engineering specialists who need Masters degrees and higher level qualifications? Are you able to recruit adequate numbers of these from Australia?
iv. Are there new areas of engineering or 'engineering-with-xxx' in which you will need to recruit?
v. What is the value to you/your company of having an education system that allows universities to create degree programs with specialist titles (as opposed to generic ones), and apparently specialist (boutique) degree programs in engineering areas?

(Academics were asked about the future mix of programs.)

<u>2: Graduate Attainment:</u> How do you rate the knowledge and skills (technical, personal and managerial) of engineering graduates and engineering professionals, in relation to those of 5, 10 and 20 years ago?

(Academics were asked to respond on their own programs)

i. The 1996 Review emphasized the need for engineering graduates to gain greater appreciation of the broader (than their engineering science specialization) role of engineering professionals;

engineering education must become more outward looking, more attuned to the real concerns of communities. To what extent have you seen this happen? Would it have enhanced your business operation and the effectiveness of your staff?

ii. How are the specific areas of innovation and creativity, sustainability and social responsibility being played out in your business; are these taken on by recent graduates?
iii. Are these broader issues being developed at the cost of lower technical attainment – bearing in mind the rapid advances in all areas of technology that contribute to engineering – are there critical problems, and how are any such resolved?
iv. Comment on the need for short courses and postgraduate education, etc. to meet new knowledge and skill demands.
v. Overall, are 2006 graduates (at all levels) as effective as engineers (though different) as those of 10 and 20 years ago, at tackling new and complex engineering, technological and engineering management problems? (Be realistic about your own level of experience and confidence and that of your peers on graduation.)

3: Perceptions of EE curriculum and its value: What were the best and worst, most relevant and least relevant aspects of your engineering education? Have your views on these changed since graduation? (This question was not asked of academics)

i. What parts of your programs provided you with specific technical knowledge and skills that you use frequently? How have these changed over your years of practice?
ii. What generic skills, such as project management and oral and written communications, were developed in your programs? Were they integrated with technical work?
iii. Were there specific areas (technical or other) of your programs that have prepared you to deal with new workplace or professional challenges?
iv. Has the mathematics and science content of your program been useful to underpin specific elements of your professional practice, for example in working with new analytical tools, instrumentation or software?
v. How important was laboratory work, and having what characteristics, to your understanding of technical material and your personal development? Can virtual laboratory work be successfully undertaken?
vi. How strongly does the design and project work you did in your program relate to your current practice?

4: Changes in Engineering Practice and Education Issues: How do you perceive that the practice of engineering in Australia is changing? Is the education system positioned to meet the challenges ahead? (Academics asked about challenges and opportunities)

i. How are corporatisation of infrastructure and globalization changing the ways you or your business practices the engineering function? (Academics asked about changes to programs)
ii. Are new regulatory environments, including more stringent OHSW, new financial and governance requirements, and workplace relations changing the ways you or your business practice the engineering function? (Academics asked about changes to programs)
iii. Are changes in the workplace (eg. introduction of new technologies, offshoring of some functions, fly-in-fly-out cycles) and in workplace relations) affected the scope and content of your engineering work, or that of your business? (Academics asked about changes to programs and study patterns)
iv. What do you see are the implications for the engineering education system? (Academics asked about need for radical changes to engineering education.)

5: Changes in Engineering Education: How do you perceive that engineering education in Australia has changed significantly in the past decade? What has been the impact and value of those changes with respect to the extent to which they have met industry needs?

i. Were you aware of/involved with the 1996 Review and its outcomes, and the extent to which they have invoked changes (see above) in accreditation, and increased focus on generic attributes and curriculum broadening? (Academics asked to comment on implementation of the Review)
ii. What other pressures do you perceive that engineering education has responded to, or failed to respond to? (This could invoke discussion about differential HECS, industry partnerships, schools outreach, research focus.)
iii. Do you have any comments on the growth of specialized (boutique) programs, and international students in engineering (particularly in master programs).
iv. Are there areas of engineering research that you or your business need that are being undertaken in new university research ventures, such as CRCs? Have you any comments about the importance or not, of linking engineering research into undergraduate curricula.

<u>6: Student demand factors:</u> What do you think are the main attractors and detractors of engineering education from the perspectives of Australian students making study choices at Year 9/10 and Year 11/12. Would you recommend an engineering degree to members of your family and friends?

i. How are all stakeholders in the engineering education enterprise doing to promote engineering education as a rewarding and flexible pathway for young people to attain leadership and influence roles?
ii. Are the images and language used to attract young people towards engineering accurate (with respect to careers and the programs of study) and appropriate for the modern generation of students?
iii. Is the high workload and extended duration of engineering programs, relative to generic science and business, a detractor, despite good career rewards and opportunities. What are the curriculum and communication challenges to the stakeholders here?
iv. What key messages should stakeholders be providing into the school sector to enhance the position of engineering? (Here we need to would work with science and mathematics to increase the proportion of school students undertaking forward-looking studies in these areas, not proposing that modern education needs to be what it was 30 years ago.)
v. Engineering often runs in families, particularly for women. Will the current generation of women (and men) engineers promote the profession as avidly as their fathers role-modeled it for them? Do you advocate for engineering amongst your family and friends?
vi. What proportion of school leavers would prefer a general degree as opposed to entering the highly specific programs we mostly operate?

<u>7: Industry Engagement:</u> How should industry best engage with engineering education?

i. Do you support the notion of much more strongly practice-based education programs with some universities, to provide clearer program differentiation? Pros and cons ?
ii. Can the need for students to earn while studying harmonise more effectively with industry's stated desire to be more engaged with the engineering education and formation processes?
iii. Can research and innovation required by industry be a more effective vehicle for university-industry partnerships? What are the relevant incentives/facilitative mechanisms, and inhibitors?
iv. Are there innovative opportunities for new university-industry partnerships in some emerging industry sectors to meet skills and innovation gaps? What needs to be done to facilitate them?

<u>8: Curriculum Changes to Increase Student Demand:</u> What changes would you propose to improve engineering education curricula to address critical future issues, including its attraction to talented students, especially women?

i. How would do you see desirability of change in the balance between technical and managerial content, and curriculum focused on personal development, particularly for the purpose of attracting school leavers with high ENTER scores and more women?
ii. How do you see the development of new curriculum methodologies, such as the incorporation of software tools and simulations, web-based learning, including for laboratories; does the nature of laboratory work in engineering need rethinking?
iii. How do you see the roles of group and individual project work in engineering education? What are the pros and cons?
iv. How do you see the value and development of approaches based on problem-based learning; the introduction of 'just-in-time' science and mathematics?
v. Should (professional) engineering go to five years minimum duration?

9: Program Accreditation: What are your opinions of the engineering accreditation process, and its focus on graduate attributes and competencies?

Preamble: the Stage 1 Competency Standards published by Engineers Australia are a fleshing out of the generic attributes, and set out in detail the knowledge, capabilities and attributes (and associated performance indicators) expected of an individual entering the profession. Implicitly these are equated with the competencies expected of a graduate of an accredited engineering education program. There is a separate standard for each of the three career levels; they need to be dynamic documents that react to changing needs, and this review is a chance to perhaps recalibrate the standards.

i. To what extent are the Competency Standards used as a reference framework for defining program outcomes and supporting academic development? What deters (or encourages) their use?
ii. Are the Competency Standards valid and relevant? Can they be improved? Who needs to do such work (eg, academics, College Boards, Accreditation Board)?

B. Student Consultations

1: Graduate Demand How is the much-publicised shortage of engineering graduates (particularly in some areas) affecting your plans and thinking about your future employment and careers?

i. Are you being 'pestered' by potential employers from particular industries? If so, what areas and industries?
ii. Are you contemplating 'changing engineering discipline' into an area of high(er) apparent demand, or moving away from your original ideas if you are in an area of apparent low graduate demand?
iii. A lot of the shortage is expressed as 'shortage of experienced' engineers? What do you feel about this? What do you want to see done to get (you) into a position to compete?
iv. What pathways do you anticipate your career taking? Do you think of yourself as 'always being an engineer', even if you may be practising management in an engineering context?
v. Are you generally optimistic about the opportunities that graduating in engineering may offer you? Does an engineering degree open more door than close them? (Eg compared with other degree paths.)
vi. Universities can create degree programs with specialist titles (as opposed to generic ones), and apparently specialist (boutique) degree programs in engineering areas. Do you have a view on

this with respect to your own choice of program and any apparent benefits/restrictions either type of program may have?

2. Academic Program: How do you rate the balance of your program, with respect to its content and focus on science and mathematics, engineering principles, study in your chosen engineering discipline, engineering practice, engineering management, and your personal development?

(Preamble: the 1996 Review emphasized the need for engineering graduates to gain greater appreciation of the broader (than their engineering science specialization) role of engineering professionals; engineering education must become more outward looking, more attuned to the real concerns of communities.)

i. Does your program have an emphasis on engineering science or engineering context? Is the balance what you expected, and in line with the ways it is promoted?

ii. How are the specific areas of innovation and creativity, sustainability and social responsibility being developed in your engineering education?

iii. Do you have adequate opportunities to develop more knowledge and skill (as you desire) in either engineering science or in engineering practice and context?

iv. What are your expectations of taking a masters degree or higher level qualifications to meet your career aspirations? Would this be a technical specialization or a management oriented degree?

v. Are you confident that you will be able to meet the challenges of graduate employment? What knowledge and skills will employers will want to employ you for; what areas will you need more development?

3. Academic Program: What are the best and worst aspects of your program, and what do you perceive to be most relevant and least relevant aspects of your engineering education?

i. What course content do you find the most and least valuable; what criteria do you use to make these judgments?

ii. What educational methodologies (lectures, laboratories, projects, etc.) lead to your best learning? Does this vary between subjects/courses?

iii. How are generic skills, such as project management and oral and written communications, being developed in your programs? Are they integrated with technical work?

iv. Are the programs meeting your expectations (for technical knowledge and professional and personal development? Do they match up with the ways they are promoted?

v. What are your observations on how the mathematics and science content of your program underpins specific elements of your engineering discipline and preparation for professional practice, for example in working with new analytical tools, instrumentation or software?

vi. How important and effective is laboratory work for understanding technical material and developing useful skills? What are your comments on virtual laboratory work?

vii. How important and effective is design and project work for developing technical and other knowledge, skills and understandings?

4. Engineering Practice: How do you perceive that the practice of engineering in Australia has changed over the past decade? How do you want to see industry and engineering practice engage with engineering education?

i. What do you know of major (eg corporatisation of infrastructure and globalization) and incremental (eg workplace reform, OHSW) changes in the ways engineering is practiced in Australia over the past decade or so? How do you think such changes may impact on you, when you are employed as a graduate engineer?

ii. What kinds of industry engagement are you having as part of your program? In what ways are these experiences positive, neutral or negative? Are there areas for improvement for your university program's interaction with industry that you can envisage, based on your own experiences?

iii. How does the need for you (assuming you are typical of most students) to earn income while studying relate positively and negatively to your ability to gain industrial experience?

5. The Future: In what technical areas and for what activities do you think that there may be critical shortages of engineers in future, and what specific, possibly new, contributions do you believe engineers will make to Australia's future prosperity, security, and well-being?

i. How do you see engineering – both technical and managerial – developing over the early years of your practice?

ii. What new areas of science and technology do you anticipate you may have to work with?

iii. What are the key 'added values' that engineers offer their employers, and society at large? Are engineers are particularly well placed (by virtue of the balance of their education) to take leadership positions in new ventures and society at large?

iv. What particular engineering challenges and opportunities does Australia have that you expect or wish to contribute to? Do these need you to develop specialist skills, eg though undertaking a masters or research degree?

6. Student Demand: What do you think are the main attractors and detractors of engineering education from the perspectives of Australian students making study choices at Year 9/10 and Year 11/12? Would you recommend an engineering degree to members of your family and friends?

i. How well are the stakeholders (mostly academics, the profession and industry) in the engineering education enterprise doing to promote engineering education as a rewarding and flexible pathway for young people to attain leadership and influence roles?

ii. Are the images and language used to attract young people towards engineering accurate (with respect to careers and the programs of study) and appropriate for the modern generation of students?

iii. Is the high workload and extended duration of engineering programs, relative to generic science and business, a detractor, despite good career rewards and opportunities? What should educators do about this?

iv. What key messages should stakeholders be providing into the school sector to enhance the position of engineering?

v. In what ways is it useful to have more or less differentiation between programs in a given discipline area (especially in the larger cities)?

7. Student Demand: What needs to be done within schools and universities to attract more students, especially women, into engineering? (Also Question 8)

i. How would do you see desirability of change in the balance between technical and managerial content, and curriculum focused on personal development, particularly for the purpose of attracting school leavers with high ENTER scores and more women?

ii. We note that engineering often runs in families, particularly for women. Is that the case for you? Will you advocate for engineering amongst your family and friends to a greater or lesser extent than you may have previously expected to?

iii. In what ways would a clearer system of 2-, 3-year, 4- and 5-year duration programs attract more students into engineering, or are there already too many choices for school leavers?

iv. What needs to be done in the promotion of engineering to school students to increase its attractiveness, noting that engineering offers many career pathways?

8. What improvements would you like to see made to engineering education programs and courses to prepare you to address future career needs within engineering?

i. How would do you see desirability of changes in the balance between technical and managerial content, and curriculum focused on personal development? How would more or less choice within the program (at all levels) be received by students? (Or should the choice be between different institutions with distinctly different programs?)

ii. How do you find software tools and simulations, web-based learning, including for laboratories; assist your learning? More or less?

iii. How do you value group and individual project work in your education? What are the pros and cons?

iv. How do you value problem-based learning; and 'just-in-time' science and mathematics (if you have experienced them)?

9. Accreditation: What do you know about the processes of engineering accreditation process, and its focus on graduate attributes and competencies?

(Preamble: the Stage 1 Competency Standards published by Engineers Australia are a fleshing out of the generic attributes, and set out in detail the knowledge, capabilities and attributes (and associated performance indicators) expected of an individual entering the profession. Implicitly these are equated with the competencies expected of a graduate of an accredited engineering education program. There is a separate standard for each of the three career levels: they need to be dynamic documents that react to changing needs, and this review is a chance to perhaps recalibrate the standards.)

i. What do you know about Accreditation? (Eg that your university has a periodic accreditation process; that Australia is part of set of international agreements that assist graduates to be recognized overseas; that accredited programs are designed to meet a set of graduate attributes and competency standards?)

ii. What do you know about 'generic attributes' (or whatever they are called in a particular university), and their relationship to how your program has been designed?

Appendix 5 Consultation schedule

A. City/university-based focus groups

city	dates (all in 2007)	universities covered	academics	students	industry
Melbourne	30/07 (AB)	Victoria U.	11	3	4
Melbourne	31/07 (AB)	Melbourne	10	16	14
Melbourne	31/07 (AB)	Latrobe	44	20	6
Melbourne	21/08	RMIT	9	4	6
Melbourne	22/08	Swinburne	12	13	5
Melbourne	23/08	Monash	20	12	N/A
Geelong	16/05	Deakin	13	20	5
Ballarat	17/05	Ballarat	13	9	14
Perth	24-25/05	WA, Murdoch, Curtin ECU	12	8	N/A
Wollongong	30/05	Wollongong*	12	2	2
Rockhampton	4/06 (with M'OK)	CQU	19	13	15
Brisbane	5/06 (with M'OK)	Queensland, QUT, USQ Griffith	20	11	0
Townsville	7/06	James Cook	14	12	18
Canberra	24/07	ANU, ADFA	25	7	2
Adelaide	26-27/07	Adelaide, Flinders, UniSA	27	14	7
Newcastle	9/08 (with M'OK)	Newcastle*	40	15	14
Sydney	2/08, 14/08, 16/08	UTS	30	20	10
Sydney	15/08, 12/10, 24/10	Sydney	18	16	10
Sydney	27/08	UNSW	10	11	N/A
Sydney	28/08	UWS	12	13	N/A
Sydney	10/10	Macquarie	2	4	N/A
Hobart	13/08 (AB)	Tasmania/AMC	10	6	8
Darwin	21/09	Charles Darwin U	10	30	6
Canberra	9/11	G8 group + *	~16	N/A	N/A

Notes: 1. All consultations were facilitated by the Project Manager, except for four led by Em. Prof Alan Bradley shown as date (AB)

2. N/A in 'industry' column indicates where local industry input was expected to be covered by Engineers Australia group.

B. Engineers Australia College Boards, etc.

city	dates (all in 2007)	board/division covered	attendees
Geelong	16/05	local Engineers Australia members	12
Perth	24/05	local Engineers Australia members	12
Adelaide	26/07	local Engineers Australia members	6
Brisbane	5/06	Brisbane Division Board members	12
Sydney	17/09	Sydney Division Board	12
Sydney	24/09	Mechanical College Board & National* Committee on Engineering Design*	18
teleconference	27/09	College Board chairs	~12
teleconference	12/10	Biomedical College	~ 5
teleconference	20/10	Environmental College Board & Society for Sustainabilit*y	~ 18
teleconference	23/10	Information, Telecommunications, and Electronics Engineering College Board	~ 8
teleconference	9/11	Structural College Board	~ 8
teleconference	27/11	Electrical College Board	~ 12
Sydney	4/12	Australian Constructors Association C'ttee*	5
Melbourne	10/12	Industry-University Workshop (AaeE Conf)	~ 60

* these groups also provided paper submissions
note: several members of Young Engineers participated meetings

C. Consultations with key individuals, outside group meetings

dates	person
31/08/07	Dr Lincoln Wood, BAESystems
3/10/07	Prof David Radcliffe, Purdue University
15/11/07	Dr Robin Batterham, President, ATSE
14/02/08	Julie Hammer, President, Engineers Australia

Appendix 6 Submissions

from	affiliation
Andrew Taylor	Senior Consultant
Em. Prof David Beanland	Former Vice Chancellor, RMIT University
Mark Bennett	student
Roger Byrne	GHD Pty. Ltd.
Anna Carew	University of Tasmania (on the EMAP project)
Conrad Drake	-
Fred Eames	RoadTek Asset Services
Stuart Green	Penrith Lakes
Peter Hoban	FIEAust
Bronwyn Holland	Women in Engineering Program, UTS
Dr W Kozlowski	-
Sally Male	National Women in Engineering Committee, Engineers Australia
George McLeod	FIEAust
Ye Yit Ooi	MIEAust
Frank Osborn	-
Larry Pigott	Greenhaven Projects Pty. Ltd.
Prof Rolf Prince	University of Sydney
Nick Proferes	MIEAust
Dr Nathan Scott	University of Western Australia
Bruce Sharp	Hydraulic Engineering Consultant, Burnell Research Laboratory
Christopher Skinner	Member, Engineers Australia National Committees on Software Engineering, and Transport Engineering
Nathan Spencer	-
Vlad Stanculescu	student, University of Western Sydney
Mark Stevens	Metso Minerals
Cmdr Dave Swan, RAN	Royal Australian Navy
Mike Swift	TRS Industrial & Marine Pty. Ltd.
James Tayler	-
Peter Thornton	WorleyParsons Rail
Matthew Vankeuk	student, University of Newcastle
John Woodside	Consulting Structural Engineer-
Peter Woolridge	FIEAust, CPEng

Appendix 7 Internationally agreed statements of competencies for the 3 levels of engineering awards

Graduate Profile Exemplars (Definitions follow in a second table.)

		Differentiating Characteristic	**… for Washington Accord Graduate**	**… for Sydney Accord Graduate**	**… for Dublin Accord Graduate**
1.	**Academic Education**	Educational depth and breadth	Completion of an accredited program of study typified by four years or more of post-secondary study.	Completion of an accredited program of study typified by three years or more of post-secondary study.	Completion of an accredited program of study typified by two years or more of post-secondary study.
2.	**Knowledge of Engineering Sciences**	Breadth and depth of education and type of knowledge, both theoretical and practical	Apply knowledge of mathematics, science, engineering fundamentals and an engineering specialization to the conceptualization of engineering models.	Apply knowledge of mathematics, science, engineering fundamentals and an engineering specialization to defined and applied engineering procedures, processes, systems or methodologies.	Apply knowledge of mathematics, science, engineering fundamentals and an engineering specialization to wide practical procedures and practices.
3.	**Problem Analysis**	Complexity of analysis	Identify, formulate, research literature and solve *complex* engineering problems reaching substantiated conclusions using first principles of mathematics and engineering sciences.	Identify, formulate, research literature and solve *broadly-defined* engineering problems reaching substantiated conclusions using analytical tools appropriate to their discipline or area of specialisation.	Identify and solve *well-defined* engineering problems reaching substantiated conclusions using codified methods of analysis specific to their field of activity.
4.	**Design/ development of solutions**	Breadth and uniqueness of engineering problems i.e. the extent to which problems are original and to which solutions have previously been identified or codified	Design solutions for *complex* engineering problems and *design* systems, components or processes that meet specified needs with appropriate consideration for public health and safety, cultural, societal, and environmental considerations.	Design solutions for *broadly- defined* engineering technology problems and *contribute to* the design of systems, components or processes to meet specified needs with appropriate consideration for public health and safety, cultural, societal, and environmental considerations.	Design solutions for *well-defined* technical problems and *assist with* the design of systems, components or processes to meet specified needs with appropriate consideration for public health and safety, cultural, societal, and environmental considerations.
5.	**Investigation**	Breadth and depth of investigation and experimentation	Conduct investigations of *complex* problems including design of experiments, analysis and interpretation of data, and synthesis of information to provide valid conclusions.	Conduct investigations of *broadly-defined* problems; locate, search and select relevant data from codes, data bases and literature, design and conduct experiments to provide valid conclusions.	Conduct investigations of *well-defined* problems; locate and search relevant codes and catalogues, conduct standard tests and measurements.
6.	**Modern Tool Usage**	Level of understanding of the appropriateness of the tool	Create, select and apply appropriate techniques, resources, and modern engineering tools, including prediction and modelling, to *complex* engineering activities, with an understanding of the limitations.	Select and apply appropriate techniques, resources, and modern engineering tools, including prediction and modelling, to *broadly-defined* engineering activities, with an understanding of the limitations.	Apply appropriate techniques, resources, and modern engineering tools to *well-defined* engineering activities, with an awareness of the limitations.

7.	**Individual and Team work**	Role in and diversity of team	Function effectively as an individual, and as a member or leader in diverse teams and in multi-disciplinary settings.	Function effectively as an individual, and as a member or leader in diverse technical teams.	Function effectively as an individual, and as a member in diverse technical teams.
8.	**Communication**	Level of communication according to type of activities performed	Communicate effectively on *complex* engineering activities with the engineering community and with society at large, such as being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.	Communicate effectively on *broadly-defined* engineering activities with the engineering community and with society at large, by being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions	Communicate effectively on *well-defined* engineering activities with the engineering community and with society at large, by being able to comprehend the work of others, document their own work, and give and receive clear instructions
9.	**The Engineer and Society**	Level of knowledge and responsibility	Demonstrate understanding of the societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to engineering practice.	Demonstrate understanding of the societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to engineering technology practice.	Demonstrate knowledge of the societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to engineering technician practice.
10.	**Ethics**	No differentiation in this characteristic	Understand and commit to professional ethics and responsibilities and norms of engineering practice.	Understand and commit to professional ethics and responsibilities and norms of engineering technology practice.	Understand and commit to professional ethics and responsibilities and norms of technician practice.
11.	**Environment and Sustainability**	No differentiation in this characteristic	Understand the impact of engineering solutions in a societal context and demonstrate knowledge of and need for sustainable development.	Understand the impact of engineering solutions in a societal context and demonstrate knowledge of and need for sustainable development.	Understand the impact of engineering solutions in a societal context and demonstrate knowledge of and need for sustainable development.
12.	**Project Management and Finance**	Level of management required for differing types of activity	Demonstrate a knowledge and understanding of management and business practices, such as risk and change management, and understand their limitations.	Demonstrate an awareness and understanding of management and business practices, such as risk and change management, and understand their limitations.	Demonstrate an awareness of management and business practices, such as risk and change management.
13.	**Life long learning**	No differentiation in this characteristic	Recognize the need for, and have the ability to engage in independent and life-long learning.	Recognize the need for, and have the ability to engage in independent and life-long learning.	Recognize the need for, and have the ability to engage in independent and life-long learning.

Common Range and Contextual Definitions

Range of Problem Solving

	Attribute	Complex Problems	Broadly-defined Problems	Well-defined Problems
1	Preamble	Engineering problems which cannot be resolved without in-depth engineering knowledge and having some or all of the following characteristics:	Engineering problems having some or all of the following characteristics:	Engineering problems having some or all of the following characteristics:
2	Range of conflicting requirements	Involve wide-ranging or conflicting technical, engineering and other issues	Involve a variety of factors which may impose conflicting constraints	Involve several issues, but with few of these exerting conflicting constraints
3	Depth of analysis required	Have no obvious solution and require abstract thinking, originality in analysis to formulate suitable models	Can be solved by application of well-proven analysis techniques	Can be solved in standardised ways
4	Depth of knowledge required	Requires in-depth knowledge that allows a fundamentals-based first principles analytical approach	Requires knowledge of principles and applied procedures or methodologies	Can be resolved using limited theoretical knowledge but normally requires extensive practical knowledge
5	Familiarity of issues	Involve infrequently encountered issues	Belong to families of familiar problems which are solved in well-accepted ways;	Are frequently encountered and thus familiar to most practitioners in the practice area
6	Level of problem	Are outside problems encompassed by standards and codes of practice for professional engineering	May be partially outside those encompassed by standards or codes of practice	Are encompassed by standards and/or documented codes of practice
7	Extent of stakeholder involvement and level of conflicting requirements	Involve diverse groups of stakeholders with widely varying needs	Involve several groups of stakeholders with differing and occasionally conflicting needs	Involve a limited range of stakeholders with differing needs
8	Consequences	Have significant consequences in a range of contexts	Have consequences which are important locally, but may extend more widely	Have consequences which are locally important and not far-reaching
9	Interdependence	Are high level problems possibly including many component parts or sub-problems	Are parts of, or systems within complex engineering problems	Are discrete components of engineering systems

Range of Engineering Activities

	Attribute	Complex Activities	Broadly-defined Activities	Well-defined Activities
1	Preamble	**Complex activities** means (*engineering)* activities or projects that have some or all of the following characteristics:	**Broadly defined activities** means (*engineering)* activities or projects that have some or all of the following characteristics:	**Well-defined activities** means *(engineering)* activities or projects that have some or all of the following characteristics:
2	Range of resources	Involve the use of diverse resources (and for this purpose resources includes people, money, equipment, materials, information and technologies)	Involve a variety of resources (and for this purposes resources includes people, money, equipment, materials, information and technologies)	Involve a limited range of resources (and for this purpose resources includes people, money, equipment, materials, information and technologies)
3	Level of interactions	Require resolution of significant problems arising from interactions between wide-ranging or conflicting technical, engineering or other issues,	Require resolution of occasional interactions between technical, engineering and other issues, of which few are conflicting	Require resolution of interactions between limited technical and engineering issues with little or no impact of wider issues
4	Innovation	Involve creative use of knowledge of engineering principles in novel ways.	Involve the use of new materials, techniques or processes in innovative ways	Involve the use of existing materials techniques, or processes in new ways
5	Consequences to society and the environment	Have significant consequences in a range of contexts	Have consequences that are most important locally, but may extend more widely	Have consequences that are locally important and not far-reaching
6	Familiarity	Can extend beyond previous experiences by applying principles-based approaches	Require a knowledge of normal operating procedures and processes	Require a knowledge of practical procedures and practices for widely-applied operations and processes

source: International Engineering Alliance Education Accords, via Engineers Australia

Appendix 8 Australian Engineering Schools and the areas of their accredited programs

								fully or provisionally accredited B.Eng programs in discipline areas (M denotes accredited award is a Masters degree: P denotes a 2-year pathway to an accredited program delivered elsewhere) Engineers Accreditation only												
university	group	location of engineering in academic structure	executive position resp. for engin'g	academic sub-structure for engineer'g	size	% int'l	Civil	Mech, Manuf, Industrial	Elec, Electron, Tele. Comp	Chemical	Mining	Software	Aerospace	Naval Arch.	Biomedical	Environmental	Mechtronics & Robotics	other	acccredited B.Tech	off-shore accredited engineering programs
Australian Defence Force Academy/UNSW	G8	2 Schools of Engineering	Heads	none	S	S	x	x	x				x						x	
The Australian National University	G8	College of Engineering & Computer Science	Dean & Director	2 eng depts	S	M		x	x			x				x	x	systems		
Macquarie University	IRU	Division of Information and Communication Sciences	Dean	1 eng dept	S	S			x										x	
The University of New South Wales	G8	Faculty of Engineering	Dean	9 eng schools	L	H	x	x	x	x	x	x	x	x	M	x	x	several		
The University of Newcastle	IRU*	Faculty of Engineering and Built Environment	Pro Vice Chancellor	2 eng schools	M	H	x	x	x	x	P	x				x	x			x
The University of Sydney	G8	Faculty of Engineering & Information Technologies	Dean	5 eng schools	L	M	x	x	x	x		x	x		x		x			
University of Technology, Sydney	ATN	Faculty of Engineering	Dean	none	L	M	x	x	x			x				x	x	several	x	x
University of Western Sydney	NGU	College of Health & Science (School of Engineering)	Executive Dean	1 eng school	M	M	x	x	x							x	x	building	x	
University of Wollongong	other *	Faculty of Engineering Faculty of Informatics	Deans (2)	FoE: 3 eng schools FoIT 1 eng school	M	S	x	x	x		x					x		materials	x	

university	group	location of engineering in academic structure	executive position resp. for engin'g	academic sub-structure for engineer'g	size	% int'l	fully or provisionally accredited B.Eng programs in discipline areas (M denotes accredited award is a Masters degree: P denotes a 2-year pathway to an accredited program delivered elsewhere) Engineers Accreditation only												acccredited B.Tech	[illegible] engineering programs
							Civil	Mech, Manuf, Industrial	Elec, Electron, Tele. Comp	Chemical	Mining	Software	Aerospace	Naval Arch.	Biomedical	Environmental	Mechtronics & Robotics	other		
Charles Darwin University	regional	Faculty of Education, Health & Science	Dean	1 eng school	S	S	x	x	x											
Central Queensland University	regional	Faculty of Science, Engineering & Health	Pro Vice Chancellor	1 eng college with 3 departments	S	S	x	x	x										x	
Griffith University	IRU	Fac of Eng. & IT (science, environment and technology group)	Pro Vice Chancellor	3 schools with eng	M	M	x		x							x		coastal		
James Cook University	IRU	Faculty of Science, Engineering & Information Technology	Pro Vice Chancellor	1 eng school	S	S	x	x	x	x						x	x			x
Queensland University of Technology	ATN	Faculty of Built Environment & Engineering	Executive Dean	2 schools with eng.	M	M	x	x	x			x	x		x	x	x		x	
The University of Queensland	G8	Faculty of Engineering, Physical Sciences & Architecture	Executive Dean	2 eng schools	L	M	x	x	x	x	x	x	x		x	x	x	several		
University of Southern Queensland	NGU	Faculty of Engineering & Surveying	Dean	none	M	M	x	x	x			x				x	x	also M.Eng. practice	x	
The Flinders University of South Australia	IRU	Faculty of Science & Engineering	Executive Dean	1 school with eng	S	M			x						x					
The University of Adelaide	G8	Faculty of Engineering, Computer & Mathematical Sciences	Executive Dean	6 schools with eng	M	M	x	x	x	x		x	x				x	several		
University of South Australia	ATN	Division of Information Technology, Engineering & the Environmant	Pro Vice Chancellor	3 schools with eng	M	H	x	x	x								x		x	x

university	group	location of engineering in academic structure	executive position resp. for engin'g	academic sub-structure for engineer'g	size	% int'l	fully or provisionally accredited B.Eng programs in discipline areas (M denotes accredited award is a Masters degree: P denotes a 2-year pathway to an accredited program delivered elsewhere) Engineers Accreditation only												acccredited B.Tech	[illegible] engineering programs
							Civil	Mech, Manuf, Industrial	Elec, Electron, Tele. Comp	Chemical	Mining	Software	Aerospace	Naval Arch.	Biomedical	Environmental	Mechtronics & Robotics	other		
University of Tasmania	other	Faculty of Science, Engineering & Technology	Dean	1 engineering school	S	H	x	x	x										x	
Australian Maritime College	other	Department of Maritime Engineering	Head	none	S	S								x				several		
Deakin University	other	Faculty of Science & Technology	Dean	1 eng school	S	M		x	x							x	x		x	x
La Trobe University	IRU	Faculty of Science, Technology & Engineering	Dean	1 eng school	S	M	x		x							x			x	
Monash University	G8	Faculty of Engineering	Dean	8 eng (various names)	L	H	x	x	x	x		x				x	x	several	x	x
RMIT University	ATN	Academic Portfolio of Science, Engineering & Technology	Pro Vice Chancellor	3 eng schools	L	H	x	x	x	x		x	x			x	x	several		x
Swinburne University of Technology	other	Faculty of Engineering and Industrial Sciences	Dean	none	L	H	x	x	x			x					x	product design		
The University of Melbourne	G8	Melbourne School of Engineering	Dean	5 eng departments	L	H	x	x	x	x		x			x	x	x			
University of Ballarat	NGU	School of Science & Engineering	Head	1 eng area	S	H	M	M	M		x						x		x	
Victoria University	NGU	Faculty of Heath, Engineering & Science	Executive Dean	2 eng schools	S	S	x	x	x								x	several	x	

							fully or provisionally accredited B.Eng programs in discipline areas (M denotes accredited award is a Masters degree: P denotes a 2-year pathway to an accredited program delivered elsewhere) Engineers Accreditation only													
university	group	location of engineering in academic structure	executive position resp. for engin'g	academic sub-structure for engineer'g	size	% int'l	Civil	Mech, Manuf, Industrial	Elec, Electron, Tele. Comp	Chemical	Mining	Software	Aerospace	Naval Arch.	Biomedical	Environmental	Mechtronics & Robotics	other	acccredited B.Tech	off-shore accredited engineering programs
Curtin University of Technology	ATN	Division of Science & Engineering	Pro Vice Chancellor	Eng. Fac headed by Dean, 5 eng depts	L	H	x	x	x	x	x	x					x		x	x
Edith Cowan University	NGU	Faculty of Computing, Health & Science	Executive Dean	1 eng school	S	M			x								x		x	x
Murdoch University	IRU	Faculty of Minerals & Energy	Faculty Dean	1 eng school: head School Dean	S	S			x	x		x							x	
The University of Western Australia	G8	Faculty of Engineering, Computing & Mathematics	Dean	5 eng schools	M	M	x	x	x	x	x	x			x		x	several		

key to groups:
ATN: Australian Technology Network
G8: Group of 8 universities
IRU: Innovative Research Universities
NGU: New Generation Universities
regional and other designations are provided only for the purposes of this report

key to size bands:
L > 2500 (max ~ 4300)
1000 < M < 2500
S < 1000 (min ~ 200)

data sources:
student numbers: DEEWR, via Engineers Australia
accredited program areas: Engineers Australia website (Dec 2007)
engineering academic structures: university websites

key to international % bands (includes offshore):
H > 25% (max ~ 47%)
12%< M < 25%
S < 12% (min ~ 1%)

note 1:
* UoW and UoNewcastle are members of the G8 Engineering Deans group

note 2: universities are not included
University of Canberra and University of New England have ceased enrolments into engineering, and have withdrawn from ACED. The University of the Sunshine Coast commenced an engineering program in 2006.

Appendix 9 Invited presentations on the project by the author

The Research Methodology for the Current National Review of Australian Engineering Education, and Initial Findings, *6th ASEE Global Colloquium on Engineering Education*, Istanbul, Turkey, 1 -4 Oct, 2007.

The Australian Review of Engineering Education, *International Conference on Engineering Education & Research (iCEER-2007)*, Melbourne, 2 – 7 December 2007.

Mathematics for Engineers: Observations from the Review of Engineering Education, *National Symposium on Mathematics Education for 21st Century Engineering Students*, RMIT University, 7 Dec 2007.

The Engineering Education Review: Issues and Prospective Outcomes, *Australasian Association for Engineering Education Conference*, Melbourne, 9 – 13 Dec 2007.

Rethinking Australian Engineering Education, *BHERT-ACED-Engineers Australia Forum 'Building Tomorrow's Engineers*, Melbourne, 20 Feb 2008.

The challenges now: recent stakeholder views, *Carrick Institute Engineering Education Futures Forum*, Queensland, 25 – 28 Mar 2008.

Presentation to the Council of Engineers Australia, 9 May 2008.

Rethinking Australia's Engineering Education, *Informa Symposium on Science and Engineering: Skills for Australia's Future*, Melbourne, 11 -12 June 2008.

Issues for Engineering and Technology Education: international and Australian perspectives, *2nd International Symposium on Advances in Technology Education (ISATE-2008*), Kumamoto, Japan, 9 – 11 Sep 2008.

Assuring Quality and Supply of Future Engineering Graduates: outcomes of the 2007 – 8 national review of Australian engineering education, *7th ASEE Global Colloquium on Engineering Education*, Cape Town, South Africa, 19 - 23 Oct 2008

Appendix 10 Definitions and Glossary

definitions used in the report

engineering school	the organisational entity (or entities) within each university that has responsibility for the provision of engineering education (see Appendix 6)
dean	university manager responsible for the development and delivery of educational programs and research, and resource allocation in an engineering school (see Appendix 6)
program	the program of study leading to a university award
course	the unit of study within a program
subject	the unit of study in the school education system
skills	includes high-level knowledge, cognitive and practical abilities, attitudes required for effective professional practice at all levels of engineering (see ref 10)

acronyms used in the main text

AaeE	Australasian Association for Engineering Education
ABS	Bureau of Statistics
ACED	Australian Council of Engineering Deans
ACEN	Advanced Engineering Capability Network
APESMA	Australian Professional Engineers, Scientists and Managers Association
AQF	Australian Qualifications Framework
ARC	Australian Research Council
ASCED	Australian Standard Classification of Education
ASEE	American Society for Engineering Education
ATN	Australian Technology Network universities (see Appendix 6)
ATSE	Academy of Technological Sciences and Engineering
BAA	Backing Australia's Ability
CAE	Colleges of Advanced Education
CDIO	'conceive-design-implement-operate
CEI	Continuing Education Initiative (a DSTO program)
CGS	Commonwealth Grant Scheme
CRC	Cooperative Research Centre
CSIRO	Commonwealth Scientific & Industrial Organisation
DEETA	Department of Education, Employment, Training & Youth Affairs
DEEWR	Department of Education, Employment and Workplace Relations
DEST	Department of Education, Science and Training
DSTO	Defence Science & Technology Organisation
EMAP	Engineering Meta-Attributes Project

FTE	Full-Time Equivalent (student)
G8	Group of Eight universities (see Appendix 6)
GCCA	Graduate Careers Council, Australia
HECS	Higher Education Contribution Scheme
IBL	industry based learning
IEA	International Engineering Alliance
iNEER	International Network for Engineering Education & Research
IRU	Innovative Research Universities (see Appendix 6)
LTPF	Learning & Teaching Performance Fund
NAE	National Academy of Engineering (USA)
NICTA	National ICT Australia
PBL	problem based learning
RQF	Research Quality Framework
SADI	Skilling Australia's Defence Industry
SME	small and medium enterprises
STEM	science, technology, engineering & mathematics
TAFE	Technical & Further Education
TNEP	The Natural Edge Program
UAI	University Admissions Index (NSW TER (Tertiary Entrance Rank); Queensland OP; Victoria ENTER)
VET	Vocational Education & Training
WiE	Women in Engineering

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