Engineering the Future

Preparing Professional Engineers for the 21st Century

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This book is dedicated to Elizabeth Gertrude Lloyd, who provided love and inspiration to Brian Lloyd throughout his lifetime of writing about the Profession of Engineering.

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The Authors

The authors are professional engineers with a diversity of experience in industry and education. Each has studied at postgraduate level and three have qualifications in management. Their combined experience embraces electrical, mechanical and civil engineering, and the public and private sectors of professional engineering practice. Each has been an active contributor to their professional bodies.

Brian Lloyd’s initial career was in electrical engineering in Victoria and Tasmania, in engineering design, construction and maintenance. He rose to a divisional management position in the water industry in Melbourne, and in 1984 took up a consultancy role in education and management. He has diplomas in engineering and business, and research degrees in the social and historical development of engineering. He has made significant and sustained contributions to the bridging of higher education and industry. His many books and publications are backed by leadership roles in research and education, and significant consultancy projects in engineering education and in industry on the roles of professional and technical personnel. In 1994 he was invited to become Adjunct Professor at Deakin University, where he has made major contributions to development of workplace-based bachelor and master degrees, and the professional Doctorate of Technology. Dr Lloyd has held executive roles in APESMA and IEAust, and was National President of IEAust in 1993.

Clive Ferguson graduated BEng(Hons) from University of Liverpool and MSc from Cranfield University. He lectured for a short time before moving to the laboratories of Lucas Aerospace for five years research on fluid flow, aircraft engines and stress analysis. Then, following roles in metal component manufacturing and as Manager, Mechanical Engineering Department, with a Saudi Arabian Engineering Consultancy, he joined the Faculty of Engineering at Ballarat University in 1984. He moved to Deakin in 1991, where he is Senior Lecturer in mechanical and manufacturing engineering. He is currently undertaking doctoral research in course development to develop ideal generic competencies in engineering graduates. He is an active contributor to IEAust in several roles.

Stuart Palmer graduated in electrical engineering with BEng(Distinction) from Ballarat. He then had 10 years of professional engineering experience in automation and control of manufacturing processes, design and construction of computer control systems, and implementation of quality systems for design and manufacturing. He completed the MBA(Technology Management) in 1994. At Deakin University since 1995, he is a Senior Lecturer in management of technology and engineering management. He is currently undertaking doctoral research for the review, development and evaluation of competencies for Australian undergraduate engineering management studies in the context of flexible learning delivery. He is an active contributor to IEAust and the Australasian Association for Engineering Education.

Michael Rice: has a long record of contribution to research and writing on the engineering labour force, particularly relating R&D to national economic performance. An engineer widely experienced in the aeronautical field, he has a Diploma in Mechanical Engineering and a Graduate Diploma in Management from RMIT University. He began in aeronautical research and, following several years as a senior aeronautical engineer, he rose to Principal Engineer, Airworthiness Standards. His experience includes assistance to a Ministerial Inquiry and Technical Adviser to a Parliamentary Standing Committee. He entered consulting practice in 1986 to specialise mainly in policy and economic issues concerning R&D, and related human resource and education issues. As a consultant to the Department of Science, he made a major contribution to the first Science Indicators Report issued by the Federal Government. He has published extensively on engineering labour force supply and demand, and is acknowledged as an Australian expert in this field.
Preface

This book is intended to have present value and future purpose. We report on the state of engineering as a profession at the end of the 20th Century in Australia. We examine where Australian engineering work force and its education have been, in order to judge where the profession is now. We then speculate a little about whither engineering might be tending, and make some tentative judgements about what to do and how to do it. We provide some foundations for questions of future policy.

In our analysis of the historical and social development of engineering employment and education, we examine the culture and ethos, and the social structures and norms of engineering as a professionalised occupation. We look at the evolution of the work force and engineering populations, and the development of the engineering associations and education within a social and historical context.

This is the latest of a series of studies of professional engineers in Australia, mapping the various stages in the development in the second half of the 20th Century. The first began as evidence presented in the Professional Engineers Case before the Conciliation and Arbitration Commission in 1959 (Lloyd & Wilkin 1958, and Barnes et al. 1958). The objectives then were to dispel ignorance concerning the knowledge base required by engineers, to describe the educational processes by which engineers qualified, and to differentiate engineers from para-professional and trade occupations.

Further research brought the book Lloyd and Wilkin (APEA 1962), and Lloyd (APEA 1968), and a new extended version in Lloyd, Stokes, Rice and Roebuck (APEA 1979). In the same year The Organisation of Engineering Work (Lloyd, Macmillan 1979) explored managerial aspects of professional engineering work, and in Manpower and Education for the Water Industry (Lloyd and Nevill, AGPS 1981) identified the beginnings of the fundamental changes that subsequently swept through the work force of the public sector.

In 1989 a different approach was taken in Lloyd, Stokes, Rice and Roebuck in New Pathways in Engineering Education, setting the scene for articulated education to Master of Technology degrees for mature engineer graduates, and Bachelor of Technology degrees for Engineering Technologists. This work laid the foundations for extension of IEAust grades to Technologists and Engineering Associates. Two years later came a historical and social analysis of the development of Australian engineering (Lloyd 1991). To mark the 50th anniversary of the formation of APEA, Lloyd and Vines (APESMA 1996) presented a history of the industrial relations of the engineering profession.

This present book is informed by all the previous studies. It is not published as an instrument of policy of any organisation, but in the interests of extending the knowledge of engineering generally and of promoting the interests of professional engineers. The authors accept responsibility for the views expressed.

Our finding is that engineering and its educational and organisational elements must adapt if the occupations of the engineering work force are to meet future challenges, just as they changed and developed during the 19th and 20th Centuries. Our principal finding is that there has been fundamental change in the nature of engineering employment, and as a consequence the social construct of professionalism has to change, and that APESMA is showing the way towards a new approach to the organisation of the profession.

Dr Brian E Lloyd, AM
Melbourne, 2001
### Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>ABS</td>
<td>Australian Bureau of Statistics</td>
</tr>
<tr>
<td>ACEA</td>
<td>Association of Consulting Engineers, Australia</td>
</tr>
<tr>
<td>ACTA</td>
<td>Australian Council on Tertiary Awards</td>
</tr>
<tr>
<td>ACTU</td>
<td>Australian Council of Trade Unions</td>
</tr>
<tr>
<td>APEA</td>
<td>Association of Professional Engineers, Australia (1946-91)</td>
</tr>
<tr>
<td>APESA</td>
<td>Association of Professional Engineers &amp; Scientists, Australia (1991-94)</td>
</tr>
<tr>
<td>APESMA</td>
<td>Association of Professional Engineers, Scientists and Managers Australia (1994)</td>
</tr>
<tr>
<td>AIEA</td>
<td>Australian Institute of Engineering Associates</td>
</tr>
<tr>
<td>ASCE</td>
<td>American Society of Civil Engineers</td>
</tr>
<tr>
<td>CPEng</td>
<td>Chartered Professional Engineer</td>
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<tr>
<td>CPD</td>
<td>Continuing professional development: maintenance of competencies and development of additional competencies. (‘Continuing professional development’ is inappropriate for para-professional occupations, for which CPD may be taken to mean ‘Continuing personal development’.)</td>
</tr>
<tr>
<td>CPS</td>
<td>Commonwealth Public Service</td>
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<tr>
<td>DEET</td>
<td>Department of Employment, Education and Training</td>
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<td>DEETYA</td>
<td>Department of Employment, Education, Training and Youth Affairs</td>
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<tr>
<td>DETYA</td>
<td>Department of Education, Training and Youth Affairs</td>
</tr>
<tr>
<td>EEA</td>
<td>Engineering Education Australia</td>
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<td>IE Aust</td>
<td>Institution of Engineers, Australia</td>
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<td>ICE</td>
<td>Institution of Civil Engineers, London</td>
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<tr>
<td>IEE</td>
<td>Institution of Electrical Engineers, London</td>
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<tr>
<td>IMechE</td>
<td>Institution of Mechanical Engineers, London</td>
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<td>MTIA</td>
<td>Metal Trades Industries Association</td>
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<td>NCSPE</td>
<td>National Competency Standards for Professional Engineers</td>
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<td>NPER</td>
<td>National Professional Engineers Register</td>
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<td>NETR</td>
<td>National Engineering Technologists Register</td>
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<tr>
<td>NSF</td>
<td>National Science Foundation (USA)</td>
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<tr>
<td>OECD</td>
<td>Organisation for Economic Co-operation and Development</td>
</tr>
<tr>
<td>PELF</td>
<td>Professional Engineering Labour Force</td>
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<td>PMG</td>
<td>Postmaster-General's Department</td>
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<tr>
<td>SARTAR</td>
<td>Standards and Routes to Australian Recognition (as a CPEng)</td>
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<tr>
<td>SECV</td>
<td>State Electricity Commission of Victoria</td>
</tr>
<tr>
<td>SECWA</td>
<td>State Energy Commission of Western Australia</td>
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<tr>
<td>TAFE</td>
<td>Technical and Further Education</td>
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<td>VET</td>
<td>Vocational Education and Training</td>
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<tr>
<td>VPSEC</td>
<td>Victorian Post Secondary Education Commission</td>
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### Semantic Change

Terminology has changed. Lloyd (1979) recommended against use of 'para-professional' because of the contradiction in imputing the same meaning to 'sub-professional', but recognised that the latter also was unsatisfactory because of the implication of subservience. At that time 'middle-level' was adopted to describe what now is accepted as 'para-professional', and the use of 'sub-professional' has ceased.

Lloyd (1979) also had trouble with the term 'technologist', because of the confusion in usage internationally. However, by 1989 it became acceptable to promote the title 'engineering technologist' as denoting a new professional occupation between the para-professional category and the professional engineer category.

By 1979 the occupational title 'engineering associate' had gained fairly wide acceptance, although there was still a strong attachment in New South Wales and elsewhere to describing para-
professional people as 'technicians'. Lloyd et al (1989) mounted a case for clarification of the two
categories: 'technician' applied to post-trade and similar level occupations, and 'engineering
associate' to describe para-professional occupations. The rationalisation of the Metal Trades
industrial awards in the early 1990s reflected that terminology.

In 1997 the IEAust responded to opinion among engineering para-professionals that the term
'associate' no longer was acceptable to them. It was a minority opinion, not backed by market
research to test the degree of acceptance that had been achieved over 25 years for the title
'engineering associate'. However, the IEAust was persuaded to substitute 'engineering officer' for
the para-professional category. The change had some force in logic, as it aligned with the widely
used 'technical officer' and 'drafting officer', but subsequently many para-professionals were against
the change. The matter was not finally resolved within IEAust by 2000.

Another important distinction is needed in connection with the term 'associate'. The descriptor
'Associate Diploma' came into use in the 1980s to denote a 2-year post-school Year 12 para-
professional qualification. Persons unfamiliar with the historical development of education tend to
confuse such qualifications with the pre-existing 3-year 'Associateship Diplomas' that were
professional qualifications. Such usage arose originally from the practice among many technical
colleges and Institutes of Technology of identifying their diploma graduates as 'Associates' an in
'Associate of the Gordon Institute of Technology'. The Perth Technical College, which offered
para-professional 'Diplomas', identified the professional level offering as the 'Associateship' course.
Therefore it is as well to differentiate the pre-1980 professional 'Associateship Diplomas' from the
more recent para-professional 'Associate Diplomas'. It is the 'ship' that makes the difference.

**Definitions**

- **Articulation**: Articulated education means the provision of a series of courses that, in themselves,
  provide occupational entry qualifications for particular work-force occupational
categories, and, in addition, provides for each such course to match into an
appropriate higher course without overlap of prior studies, and recognition of
appropriate experiential learning.

- **Co-operative**: Co-operative education is a mode of delivery in which blocks of full-time studies are
  alternated with work experience. (Alternative: sandwich courses)

- **Course**: The total study needed to obtain a particular qualification, that is, a formalised set of
  learning components that provide the knowledge and skills required for an identified
qualification at a defined level of attainment in a field of study.

- **Engineer**: In Australia, a person qualified for Graduate or Corporate membership of IEAust.
  (Synonym: Professional Engineer)

- **Formation**: The sum of education, training, work-based learning and experience that provides
  ability to apply the knowledge and skills needed by a person in an occupation.

- **Full-time**: The mode of educational delivery in which the student attends classes for the full
  period in each week of an academic session. (The expression 'on a full-time basis'
  adds nothing to 'full-time'.)

- **Master degree**: A postgraduate degree conferred on completion of a course of study or a thesis
  describing a program of research, or a combination of both. (The descriptor 'Masters
degree' sometimes is used, but it is not clear what adding the 's' is intended to mean.
Some universities use 'Master's degree' to denote a degree possessed by a 'master'.)

- **Module**: A self-contained unit of study representing a period of classroom contact, or its
equivalent. TAFE and VET programs tend to be expressed in modules, representing
approximately 50% of a Unit, as defined here.

- **Part-time**: The mode of educational delivery in which the student attends classes for a limited
  period in each week of an academic session, while engaging in employment during
most or all of normal working hours. Part-time evening attendance occurs entirely
outside working hours. Part-time day release entails release from employment for
period during working hours. (The expression 'on a part-time basis' adds nothing to 'part-time'.

Program A course, or a planned sequence of related studies leading to a qualification for a particular person. A total program might constitute a series of articulated courses.

Professional Engineer In Australia, a person qualified for Graduate or Corporate membership of IEAust. (Synonym: Engineer)

Subject A component of learning taken in a stage of a course, dealing with a particular topic or area of study. Subjects may be called ‘units’ and may comprise one or more modules.

Unit A component of learning taken in a stage of a course, dealing with a particular topic or area of study. In this book 'unit' has a specific meaning: the study load equivalent to one eighth of a normal full-time year of studies. Units may comprise one or more modules.

Postnominals
There is a high degree of standardisation in Australia in the postnominals applicable to academic credentials and professional memberships. However, not everyone appreciates the nuances involved. The more usual postnominals encountered in this book are:

**Academic Postnominals**

**BE** Bachelor of Engineering, generally in Australian universities, and in Ireland and some universities in other countries.

**BEng** Bachelor of Engineering, in some Australian universities (previously Colleges of Advanced education), and in Britain and some universities in other countries.

**BS** Bachelor of Science in USA, where the first undergraduate engineering and engineering technology degrees also generally are the BS, as in BSEE for electrical engineering, or BSET for engineering technology.

**BSc** Bachelor of Science, in Australia and Britain. (In previous times in Britain, also the degree for engineering.)

**BTech** Bachelor of Technology, in Australia for 3-year courses, but other meanings in some other countries.

**ME** Master of Engineering, generally in Australian universities, and some universities in other countries.

**MEng** Master of Engineering, in some Australian universities universities (previously Colleges of Advanced education), and in Britain and some universities in other countries.

**MEngSc** Master of Engineering Science, [Sometimes pronounced 'em-eng-sye', leading to the erroneous MEngSci.]

**MTech** Master of Technology.

**Professional and Para-professional Postnominals**
The following postnominals designate grades of membership in IEAust:

**CPEng** Chartered Professional Engineer

**CEngT** Chartered Engineering Technologist

**CEngO** Chartered Engineering Officer (Engineering Associate)

**FIEAust** Fellow of the Institution of Engineers, Australia (Engineer)

**MIEAust** Member of the Institution of Engineers, Australia (Engineer)

**TFIEAust** Technologist Fellow of the Institution of Engineers, Australia

**TMIEAust** Technologist Member of the Institution of Engineers, Australia

**OFIEAust** Officer Fellow of the Institution of Engineers, Australia (Engineering Associate)

**OMIEAust** Officer Member of the Institution of Engineers, Australia (Engineering Associate)
Chapter 1
Milestones, Crossroads and Opportunities

By Brian E Lloyd

Introduction
A New Golden Age
Optimists believe that Australia is poised on the brink of the third ‘golden age’. In this book we examine the state of readiness of the Profession of Engineering to contribute to the new age. Our findings are that the traditional ways of organising the Profession, as a construct of the Industrial Revolution, are largely irrelevant to the new age: unless the profession re-invents itself, it is likely that its future effectiveness will be impaired. That would dim the brightness of the third 'golden age'.

The first 'golden age' from 1860 to 1890 followed gold discoveries in the 1850s. Population growth and prosperity of unimagined dimensions were underpinned by engineers providing the national infrastructure and a manufacturing industry. Then depressions, wars and stultified economic progress were mitigated by Federation and an emerging national identity, and the unified national Profession of Engineering. The second ‘golden age’ followed World War II and lasted until about 1975. Western economies saw unprecedented growth, peace and prosperity. Australian engineering became better organised and remunerated. Then came flagging economic performance leading to the traumatic social and industrial adjustments of the 1990s, as Australia grappled with globalisation and the destructive ideologies of rationalist economics. As the Profession of Engineering grew, engineers became indifferent to the ideals of professionalisation. As Australia emerges from the depressing 1990s to face the new golden age of the 21st Century, a revitalised Profession of Engineering will be essential if we are to re-assert our place in the world. A condition for that will be a civil society in which the value of professional and ethical practice in engineering is encouraged and appreciated.

The scope of this book is made clear in reference to 'engineer' as a person who engages in engineering work while fulfilling accepted contemporary community criteria applying to a professional occupation. 'Engineer' is synonymous with 'professional engineer', a person qualified for professional engineering membership of IEAust. Attention also is paid to the new occupation of Engineering Technologist, and in passing to the para-professional category. The core issues traversed are the evolution of engineering education, the expanding spectrum of engineering work, and the role and influence of the professional associations in employment.

Australia’s place in the world ... is not as part of one region or another; it is as a global nation. Australia’s destiny can now be seen more clearly than at any time since European settlement. It is a migrant nation built on the foundations of the best liberal Western values. That destiny is to be a global nation in this globalising world. This is the reason why Australia will enjoy its third ‘golden age’ in the new millennium.


Milestones in the Journey of Engineering
This book reviews the developing culture of Australian engineering to the end of the 20th Century. We frame the story in the context of historical, social and educational analyses of the changing circumstances of engineering practice. As the engineering-based industries of Australia progressed from colonial days to modern times, they navigated many milestones and crossroads in depressions, wars, technological revolutions and economic and political ideologies. The physical development and achievements of engineering industries, and the building of many great private and public corporations, are not the subject of this book. We are concerned mainly with the professional engineering work force.

Two external influences have supplied and nurtured Australian engineers. The first is education, where intellectual power is stimulated and from which engineering leaders spring. The second is the professional associations, providing occupational identity and sustaining intellectual standards, social responsibilities and professional leadership. In both there were milestones and crossroads along the journey, and we review the most important of them before peering uncertainly into a murky future. The first defining milestone of the 20th Century was in 1919 when engineers were united by the Institution of Engineers, Australia (IEAust) as a national profession based upon qualifications and certified ex-
perience. The second milestone was passed in 1946, with formation of the Association of Professional Engineers Australia (APEA) to seek salary levels appropriate to professional performance and contribution. Success came as the third milestone in 1961, when the Professional Engineers Award established decent salary levels and professional recognition for engineers with degrees and diplomas, adding strength to IEAust for certification of qualifications and experience. The Award brought a need for properly formed para-professional categories, as well as motivating a review of professional engineering education. There was a minor crossroads in the early 1970s, when IEAust almost conceded the title 'engineer' to para-professionals, a disaster avoided through pressure from APEA.

The fourth milestone was passed in 1973: formation of the Australian Institute of Engineering Associates (AIEA) as the national body for engineering para-professionals. The fifth milestone in 1980 brought IEAust recognition as a professional engineer based upon 4-year qualifications, making engineering a degree-entry profession. In the linear journey from 1920 to the 1980s the traditional model of professionalism was reinforced and not seriously challenged.

The first major crossroad was negotiated in the late 1980s, when social change and labour market ideologies brought a drive for competency-based professional recognition without regard to education or qualifications. Again the occupational identity of 'engineer' was in under threat. Had IEAust allowed the 'competency without qualifications' ideology to prevail, the title 'engineer' would have gained legal standing in industrial awards for para-professionals and others 'certified' as 'engineers'. But IEAust took up the challenge, defined the new professional occupation of Engineering Technologist based upon a 3-year qualification, and confirmed the para-professional occupation of Engineering Associate with 2-year qualifications.

The Competency Standards including educational benchmarks were accepted by governments and other stakeholders in the work-force. In the process the sixth milestone was passed in 1991 when the IEAust membership was extended to include Engineering Technologists and Engineering Associates in specifically defined membership categories.

The seventh milestone brought title Chartered Professional Engineer (CPEng) for Corporate Members, with criteria harmonised with Registration and with the status of Experienced Engineer under the Professional Engineers Awards. In passing those milestones, the occupational identity of professional engineers was underpinned by definitional and educational differentiation from the other two categories, and by creating ethical obligations on all members accurately to describe their occupational standing. For all who belonged to IEAust the title 'engineer' was confined to Professional Engineers. Later the titles Chartered Engineering Technologist and Chartered Engineering Officer (Associate) were adopted, further reinforcing the identity of each category.

Thus, by the late 1990s the Profession of Engineering was in good shape. All the important elements of a coordinated system of qualifications, role definitions and occupational terminology were in place. The challenge remaining was the slide in allegiance to IEAust.

Crossroads Ahead

The systematic alignment of qualifications and occupational identity did not last. In the late 1990s, IEAust brought professional occupational identity into jeopardy. A decision to rescind the ethical obligation to confine 'engineer' to the profession was made without announcement or consultation, and allows any technologist or para-professional member of IEAust to call himself or herself an 'engineer'.

Then came disconnection of Member of IEAust from CPEng and raising the bar for admission to CPEng, disrupting the previous harmonised system and moving towards exclusivity rather than inclusivity. By century-end the allegiance to IEAust of working age engineers in Australia was approaching 20 per cent, and these actions could only hasten the decline. The IEAust was losing its way.

By century-end these factors were exacerbated by massive shifts and uncertainties in employment, but the leaders of IEAust displayed no signposts as they engaged in internal re-arrangements not relevant to the professional lives of engineers at large. Furthermore, in engineering education there was a blossoming of new specialisms, but one change required above all others did not seem to enter the consciousness of many engineering educators: the need to prepare undergraduates for survival and leadership in the new world where business and human relations were the imperatives of success and effective engineering practice.
Elements of Change

Views of the social and economic change brought about by globalisation are provided by Friedman (1999), Oxley (2000), and Latham (1998), who provide international and Australian backdrops for our investigation of engineering in Australia as we address several aspects:

**Professionalisation:** Engineering formation evolved from industrial age pupilship and apprenticeship to formal education, but with little differentiation in the work force from unqualified 'engineers' until mid-20th Century. Then in the deregulated 1990s, blurring of occupational identity arose again, and reduced allegiance to IEAust challenged the industrial age construct of professionalisation in engineering.

**Education:** Development of engineering schools, rejection in 1920 of informal routes to recognition by IEAust, increasing educational standards in diplomas and degrees, evolved after 1980 to 4-year degree access to professional recognition. The scope of engineering education then remained stable until the last decade of the 20th Century, when proliferation of specialisms extended boundaries. New approaches are needed in delivery, teaching and assessment to accommodate a new attribute-based view of graduate effectiveness.

**Facilitation of Access:** From the late 19th Century the two educational pathways to professional engineer status were universities for those with secondary schooling, and technical colleges providing wider access. Change late in the 20th Century saw the demise of the professional diploma route, but proliferation of university engineering schools, and differentiation from para-professional occupations that required appropriate technical education. While distance education is not new, in the 1990s it began to provide expanded opportunities for continuing professional development, and access to professional qualifications for mature candidates. However, by 2000, conservatism and financial stringencies were placing articulated education beyond the reach of many potential candidates.

**Demographics:** The original source of engineers in Australia was immigration, then local pupillage and apprenticeship, then formal education. The Professional Engineering Labour Force grew from about 1050 engineers at the beginning of the 20th Century to nearly 150,000 at the beginning of the 21st Century. It included significant numbers of female engineers, much higher than expected graduation rates and high immigration numbers.

**Professional Paradigms:** Australian engineering was crucial in building the national infrastructure and developing the mining industry, with a strong public sector ethos and a focus on construction and manufacturing. The paradigm was of stability of employment, careers in hierarchical command and control organisations, but little education in management. Change in the last decades of the 20th Century saw massive shifts to the private sector, reduced career opportunities in middle management, the uncertainties of contingent employment, and self-directed professional development in technology and management. Change was heralded by IEAust in 1990 with a policy of 10 per cent of undergraduate studies devoted to management, but by 2000 the Policy was weakened and many engineering educators had not yet understood the need for such studies. In contrast, the MBA in Technology Management provided by APESMA was directed to the professional survival of engineers.

**Democratisation of Work:** At the end of the 20th Century, digital electronics, computers, the Web, fibre optics, satellite communications and mobile telephones contributed vastly to democratisation of technology and information. The demise of middle management and strategies for outsourcing contributed to democratising knowledge and information sources. With increasing numbers of contract engineers self-identified as hired guns, the trade-offs for self-reliance attenuated their self-identification as professional people.

**Globalisation:** Engineering in Australia originated in the Anglo-American traditions of the 19th Century. Until the mid-20th Century it developed in relative isolation in the public sector concentrating on infrastructure construction and in many private organisations as outposts of foreign corporations. Rapid and fundamental change in the last decades of the 20th Century saw IEAust develop reciprocal overseas recognition of Australian engineering qualifications, internationalisation of many Australian consulting practices, and growth in multi-national corporations. Mutual recognition of qualifications in the globalised business environment became a major issue for professional engineers moving out of, and in to, Australia. In the 1990s APESMA began forging linkages with foreign counterparts in global alliances of professional employees.

Globalisation as the Backdrop

The first era of globalisation began in 1844 when Samuel Morse sent a message by electrical wires. By 1872 Australia was wired into the global system when the Overland Telegraph linked Adelaide to Darwin and Europe. Change was dramatic: Australia hitherto was isolated at the end of the Earth, and suddenly the turnaround time for communication was reduced from 6 months to a few hours. Impacts on news, financial markets and trade were enormous.

Speedy communication, steam-powered transport and mass produced consumer goods shrunk the world as flows of goods, information and capital increased dramatically. The conventional view is that the Industrial Revolution ended with the 19th Century, just before Dr Lee De Forest made the first triode vacuum tube to spark off the age of electronics. The first era of globalisation continued to the 1920s, by which time the telephone was well established and radio broadcasting was a reality. The age
of electronics, the motor car and aeroplanes was about to deliver benefits beyond the dreams of human-kind.

According to Friedman (1999), the first era of globalisation was disrupted by World War I, the Russian Revolution and the Depression. These events changed national boundaries and ideologies. For half a century after 1946 the metaphor for the world situation was the Iron Curtain, with world leaders in the US and Russia nervously eyeing red telephones and nuclear missile buttons. After 1961, the year Lee de Forest died, the Berlin Wall went up, but technological advance was inexorable. The era of vacuum-tube electronics was almost at an end. In 1948 the first transistor heralded the age of solid state electronics. From the transistor flowed digital electronics, computer networks and the Internet. Then suddenly in 1989 the Berlin Wall came down, to release the second era of globalisation. The new era was fuelled by flows of information and capital, gathering pace in the 1990s, and bringing an international labour market for engineers. In Australia privatisation of infrastructure enterprises disrupted many professional lives.

Friedman notes that 'technologies allow companies to locate different parts of their production, research and marketing in different countries, but still tie them together through computers and teleconferencing as though they were in one place. . . . If the first era of globalisation shrunk the world from a size large to a size medium, this era of globalisation is shrinking the world from a size medium to a size small.' The second era of globalisation was marked by free-market capitalism and a backlash against it. The globalisation system integrates markets, nations and technologies enabling individuals, corporations and nations to reach around the world further, deeper and cheaper than ever before.

The symbol of the Cold War was a wall that reminded everyone of the risk of nuclear conflict. The new defining metaphors are a world without walls, and the World Wide Web almost autonomous in its reach and nature. It has no-one in charge. The first era of globalisation was terminated by the rise of non-democratic systems of socialism, communism and fascism, as reactions against the Darwinian brutalities of free-market capitalism. There may be similar risks in the second era of a backlash from those left behind by the uncritical adoption of the new free-market system. It must be hoped that in the new age, globalisation will include fairness, and that nations and corporations will adopt and adhere to a common set of rules befitting civil societies.

The evolution of Australian engineering may be related to globalisation. Phase 1 coincided with the first era of globalisation, ending in 1919 with formation of IEAust. Phase 2 ended in 1979 at the point when Australian engineering became a degree-entry profession. The beginning of Phase 3 in 1980 anticipated the second era of globalisation, especially in international recognition and employment of Australian engineers. Phase 4 will come with the 21st Century.
Philosophies of Engineering

An Employee Profession

This book is based on an understanding of the nature of engineering as a profession, and some features are considered here. The conventional ideal of professionalism needs to be moderated when discussing engineers, who predominantly are employees. The traditional professional stereotype is medicine practised in a state of individual autonomy, while engineering is practised largely in a state of administrative subordination. Apart from the few engineers who control consulting practices, most engineers in large and small organisations, and contract engineers, are employees responding to others who represent the owners. Engineers normally have autonomy over the technology of their work, but they respond to 'client' need through the employing enterprise. This book is concerned predominantly with employee engineers.

Modern definitions of engineering encapsulate the qualifications, science, technology, and the societal and economic ends towards which engineering is directed. Therefore evolution of engineering has to be considered in three strands: the work force and its industry context, the professional associations defining the horizontal and vertical boundaries of the occupation, and the educational processes that respond to these factors in complex interactions. The spectrum of engineering-based work from trade level to the professional level changes with time, giving rise to evolution of new occupational categories. Roles that change and overlap with time cause continuous change in learning needs. It was not until the 1960s that para-professional occupations were defined and specific education provided for them. By the 1990s the scope of professional practice was extended in the new occupation of Engineering Technologist.

Engineering Uncertainties

The outcomes of engineering: telecommunications, computers, manufactured products, transport, water and power systems, influence civilisation and shape the social order. Yet a simple minded media, and uninformed managers, treat engineering outcomes as mysterious technology cargo, delivered as artefacts in a fully perfected forms from some scientific heaven: they fail to understand that every engineering process, construction or product is an outcome of the complex interactions of human values, knowledge, skills and limitations.

Engineers depend upon theoretical tools and data derived from science, invention, engineering research, design, production and testing. While striving for decisiveness and certainty, uncertainty always is present as an uncomfortable condition, until requirements are defined. Then theory is applied to achieve predictable outcomes through iterations as uncertainties and risks are reduced. After painstaking testing and experience in real-life applications, approaches and methods become theories to guide future practice. Often the uncertainties inherent in pushing the boundaries are masked in a sanitised portrayal of exactness and efficiency. The challenge is to recognise that expertise in the human element is just as important as technical analysis and synthesis. Accumulation of engineering knowledge depends not only on movement from subjective experience to objective theory, but also on the informal, collective way in which engineering decisions often arise. That the engineering process requires long-term continuity emphasises the risks in the now widespread strategies for contingent employment of professional engineers. This issue is fundamental in the paradigm shifts of the 1990s.

Engineering, Technology and Science

Engineering is distinguished from technology and science. Technology is the body of knowledge and devices adapting the physical world to human needs, within the natural laws of science. It involves costs and practicalities, ingenuity and creativity, and often intractable areas of science. Technology underpins trade and para-professional work as well as professional work. The ends of technology, the way it affects human society, and the form of technology itself, are shaped by the social, economic and cultural contexts in which it operates. Engineering developed from a need for creation of artefacts or systems of technology, requiring organisation of technical, human, physical and financial resources on a scale beyond the capability of individuals. The Industrial Revolution brought a need for the design of
machines and systems, and engineers moved beyond empirical creativity by acquiring skills in experiment, mathematical analysis and precise measurement to enable prediction of behaviour of materials, machines and systems.

The community benefits from engineering projects but also bears the consequences of any unintended side-effects in the achievement of mutually agreed goals and standards. Engineering flourishes in a society that encourages research and technological development, but there are differences in the standpoints of engineers and scientists derived from the differences in their educational formation and approaches in work. The idea of pure science implies the extension and refinement of knowledge by research, often practised in multi-disciplinary teams with specific aims. Uninformed policy makers assume scientists have a monopoly on research, and that the work of scientists is confined to research. Another uninformed view omits consideration of Development and Commercialisation in the achievement of commercial outcomes. While science predominates in biological and many process industries, engineers predominate in all phases of Research and Development in the manufacturing and infrastructure industries. In Australia some 15,000 engineers engage in these functions.

There are some 300,000 persons of working age in Australia qualified in science, and fewer than 10 per cent of them engage in activities associated with scientific R&D, most employed in academic or government institutions. Others apply the methods of science in activities such as analysis for quality control, or geological exploration or mapping. Many work in agricultural or paramedical occupations. But the majority of science graduates never engage in any form of scientific activities.

In engineering, the disciplines of Civil, Electrical and Electronic, Mechanical and Chemical Engineering predominated during the 20th Century. Other specialisms include environmental, aeronautical, agricultural, materials and mining, and the new specialisms in computing and software engineering arose in the 1990s. The trend is towards more in electronics and computing, and fewer in civil and electrical power engineering.

The occupational term Technologist is used in different ways. There are Food Technologists and Medical Laboratory Technologists, and the like. Engineering Technologists are 3-year graduates, differentiated from Professional Engineers who are 4-year graduates, both being from education based on mathematics and science, engineering sciences, design and resource organisation. Some fields of applied science, such as surveying and metallurgy, fall within the generality of 'technology' and require similar theoretical bases to engineers. Engineers predominate in occupations that often are lumped together under the term 'technology'. In 2000 the approximate numbers of ‘technologists’ under age 65 in Australia were estimated to be:5

<table>
<thead>
<tr>
<th>Professionals</th>
<th>Numbers</th>
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<tbody>
<tr>
<td>Engineers (147,000) and Engineering Technologists</td>
<td>150,000</td>
</tr>
<tr>
<td>Surveyors</td>
<td>5,000</td>
</tr>
<tr>
<td>Metallurgists and similar</td>
<td>10,000</td>
</tr>
<tr>
<td>Medical laboratory technologists and other applied scientists</td>
<td>18,000</td>
</tr>
<tr>
<td>Total</td>
<td>183,000</td>
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</tbody>
</table>

The principal trends in the functions of engineers may be derived from by surveys.6 Table 1-1 provides a distillation of data over three decades, aggregated under the headings of the main Competency Units in the National Competency Standards for Professional Engineers (1998).

### Table 1-1

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</thead>
<tbody>
<tr>
<td>Research, Development</td>
<td>7</td>
<td>7</td>
<td>9</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>Design/Investigation &amp; Reporting</td>
<td>26</td>
<td>24</td>
<td>27</td>
<td>26</td>
<td>21</td>
<td>25</td>
</tr>
<tr>
<td>Business/Project Management</td>
<td>42</td>
<td>33</td>
<td>36</td>
<td>41</td>
<td>44</td>
<td>39</td>
</tr>
<tr>
<td>Engineering Operations</td>
<td>25</td>
<td>37</td>
<td>28</td>
<td>28</td>
<td>29</td>
<td>29</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>100</td>
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</tbody>
</table>

Because survey questions may elicit differing interpretations, Design, Planning, Investigation and Reporting are aggregated. In the past Project Management was not separated from Management, and these functions also are aggregated. Engineering Operations combines construction, production, maintenance, operations, marketing and sales, and education. While there has been difference in the surveys, these aggregations produce an unexpected consistency since 1971. No major shift is evident between the broad functional categories.
The significant change not tabulated is the shift from the public to the private sector. Until the 1960s some 60 per cent of engineers were employed in Federal, State and Local Government and in Education. By 2000 the proportion was well under 20 per cent. Large public sector enterprises now contribute little Australian engineering capability, as they did in the previous era by providing initial professional development for graduates in design and operations.

In the 1990s economic policy makers began to regard engineering expertise as a commodity to be purchased when needed, omitting consideration of accumulated expertise and neglecting the vital questions: who makes the decision as to the need to engage appropriate professional expertise, and who has the expertise to manage such expertise? Such 'rationalist' cargo cult approaches are discredited by those who understand that the brainpower of professional people should be counted among the vital assets in the balance sheet.

The IEAust has shown leadership in identifying the problem of the ‘uninformed client’, as professional engineering expertise, particularly in public sector organisations, has been depleted to the extent that insufficient capability remains to secure adequate engineering and related services through outsourcing. The shift from the public sector, and mindless ‘outsourcing’ of contingent expertise, have become major detrimental factors in the new engineering paradigm.

It is time we rated the capacity to adapt as Australia's real advantage. The 21st century will be the first wired century and only those who adapt will thrive. This is why Australia will succeed in the 21st century. (Oxley 2000)

Australia’s Engineering in Context
An identified resurgence of Australian manufactured exports is associated by informed commentators, such as Oxley (2000), with the excellence achieved by many engineering-based enterprises. Australian manufacturers did not have much incentive to develop exports until the value of our dollar fell as a result of floating it, thus making Australian exports cheaper on world markets. But it took some time for manufactured exports to grow, because manufacturers were not experienced in the export businesses, and had to reposition their enterprises before exporting could be developed. Oxley (2000, pp.111-3) makes interesting observations:

There was, however, something else that was notable. Among all the industries which exported, the engineering input is significant. In retrospect, it is clear that Australia had a significant comparative advantage in engineering and industrial science which it had not recognised, and this was the critical base for competitiveness in those manufacturing industries which commenced to export without subsidies. . . .

Australia has a wider and deeper industrial and scientific base than all the Asian countries, with the exception of Japan. Korea has some industries, such as heavy shipbuilding, that we do not have, but most other manufacturing in the Asian region relies on low labour costs, and that includes most of the semiconductor manufacturing in the region. Australia, for example, has a much greater number of registered industrial standards than any other economy in the region, bar Japan. Australian engineers are well-trained, not costly (ask any engineer and they will be quick to tell you that they are underpaid) and typically innovative. This is a consequence of having, over the years, to provide services to an economy which is small in scale, in which production runs are limited and where highly specialised skills are not easily accessible. . . .

Many Australian engineering manufacturers are successful exporters. . . . Why did they start to export in the 1980s? Because everyone else started to talk exports, and things didn't look so good in Australia. Why did they keep exporting once things started to look up? Because they saw the prospects for more significant businesses if they exported. There has been a cultural shift in attitudes among Australian executives which should not be underrated.

On pages183-5 he continues (emphasis added):

The people who benefit most from markets are those who can buy and sell in them. . . . Globalisation has made the world economy the biggest market we have ever seen, and it will become even bigger in the 21st century. Those who can trade in it will do better than those who cannot. Australia is now ready to deal in it with a capacity which is entirely new.

In the second half of the twentieth century, the biggest stalls and biggest sales in this market were for manufactured products. For most of the twentieth century Australia had nothing much to offer at these stalls. By century's end, however, Australian manufacturing was globally competitive. Australia was exporting in all sectors of its economy - agriculture, minerals, services and manufacturing.

Few countries in the world have the capacity to export from all sectors of their economies. Usually this is a feature of large economies, like the United States. The ability to trade in all sectors, and therefore to all regions of the world, creates a valuable durability in the global economy. It gives natural protection against being buffeted by recession in one part of the world.
We have always been competitive exporters of agriculture and minerals. Business in those areas will stay brisk. Services will also be a high growth area. Australia can achieve striking growth in tourism. But manufacturing will remain the biggest area of world trade, and the potential for growth in exports by Australian manufacturers is enormous. They are just at the beginning of this process.

Australia is ready to deal in this market for a more fundamental reason than that it has removed protection of manufacturing. The tearing away of protection also required a change in outlook. We had to shake off the boom mentality, the idea that wealth naturally came our way because of a blessed inheritance. Australians at last understand that prosperity is won with effort and excellence. We have started to value excellence. . . . Being competitive and IT-literate are essential factors for success in the 21st century. But more is needed. The successful countries will have to have the right culture. Societies have to be able to cope with the stresses which the high rate of change will induce.

These optimistic prognostications, by a highly experienced diplomat, represent a somewhat idealised external view of engineering, viewed as a source of knowledge and expertise. In this book we view engineering from the inside, and we argue that the occupation of professional engineering is most productive and effective when practised within a professionalised ethical framework. We conclude that the past Australian paradigm of engineering is out of date and irrelevant to a significant proportion of engineers. We observe further that their rejection of institutionalised professionalisation as a way of life will result in less than optimal performance in their contribution to Australia’s industrial performance.

Engineering Beyond 2000
Quantity and Quality of Professional Engineers

Industry-based research and development provides the key to development of the globally competitive manufacturing industry advocated by Oxley (2000). Contrary to conventional wisdom, most such activity is the province of engineers. A nation’s ability to undertake research and development in industry is dependent on the availability of an adequate supply of comparatively young engineers qualified in an electronic or mechanical or related specialism. That the other Pacific rim nations are aware of this is demonstrated by the high proportion of graduates in engineering in those countries. In Singapore nearly every second male graduate is an engineer.

There was a markedly rapid growth in the numbers of men and women enrolled in engineering in Australia in the first half of the 1990s, but growth virtually ceased after 1996. The reasons are not known but it is not unlikely that the lack of a clear community image of the nature of the work of the professional engineer is a major factor. The Australian engineering profession is virtually invisible in the media, especially in relation to discussions on economic prosperity. The contrast between the major business magazines of Australia and the United States illustrates the point. The American magazine Business Week includes the words engineer or engineering frequently. It is very rare for the Australian Business Review Weekly to refer to engineers or their work: if engineering appears at all, it refers to metal manufacturing. Nothing could better illustrate the difference between the industry-orientated cultures of Australia and America.

In the first decade of the 21st Century the likely stabilisation in the number of Australians completing first degrees in engineering will place a severe limit upon Australia’s potential to increase research and development in industry to an adequate level. To counter that to some extent, the intellectual quality of the Australian profession is improving. Australian engineers are making energetic efforts to lift their game by devoting considerable effort to improving their educational qualifications, to the point where engineering might rate among the best educated of all the professions. At the end of the 1980s fewer than 8 per cent of new engineering graduates went on to gain master degrees. By 2000 nearly 13 per cent of engineers were acquiring master degrees in engineering. Similarly, there has been a marked increase in engineers proceeding to doctoral degrees: in recent years over 6 per cent – a higher proportion than in the United States. At the same time large numbers of engineers are gaining higher degrees in business and management.

What Does the Future Hold for Engineering?

Ultimately engineering is shaped by the society that benefits from it. When we contemplate Phase 4 of engineering beginning in 2001 with the new millennium, will there be further profound changes in the opening decades of the 21st Century? Certainly there will be. Will globalisation bring societal reactions against adverse outcomes? Very likely. Will engineering be seen more as a human enterprise, not an autonomous technical force? The awakening has begun.
At the beginning of the 20th Century the engineering-based work force comprised professionals, supervisors and managers, tradespeople and general labour, with fuzzy boundaries and little connection between work roles and education. By the end of the 20th Century the enlarged spectrum of occupations had the potential for systematic role definitions strongly linked to education and qualifications and to occupational identity, but the realisation of that potential was becoming attenuated by an absence of enlightened leadership from IEng Aust.

Looking ahead a few decades, is it likely that walls between professional occupations will become more fuzzy? It does seem likely. Will the horizontal boundaries of engineering be further expanded by new specialisms developed in education? That seems very likely too: it has begun. Will the horizontal boundaries around engineering eventually disappear? That seems possible in the longer term. Will some fields of engineering need to be well informed about the life sciences? Yes. Creativity and innovation depend upon contributions from all categories in the work force, and organisational survival depends upon a culture of continuous learning at all levels. An understanding of this began in the last decade of the 20th Century, but casualisation of the professional work force then became an inhibiting factor. Effective performance in the knowledge age requires continuing professional development for the professional categories, and access to updating and reskilling for para-professional and skilled categories. Some possible developments in the nature of engineering and technology employment, and of possible responses of tertiary education enterprise in the 21st Century, are canvassed later in the book.

The final questions that cannot be answered with any certainty are: could the new journey see the profession of engineering emerge in a new form? The answer is a probable 'Yes'. Will the professional occupational identity of the engineer disappear? Perhaps: much depends on what happens overseas. It certainly will be different.

There is an urgent need for the emergence of a new form of professional association that will serve the needs, and gain the allegiance, of professional engineers and engineering technologists, and to foster a greatly enhanced public and industry understanding of the importance of their roles in achieving national prosperity.

The crossroads for Australian engineering in the 21st Century are serious and fundamental. Strategies for the early decades of the new century are unclear. By 2000 APESMA was developing many new ways of responding to the social and professional needs of engineers and related professionals. Perhaps a new roadmap is being drawn.

Notes to Chapter 1

1 The final decision on 'Officer' or 'Associate' was up in the air at the time of writing. 'Officer' was written into IEng Aust Bye-laws, but the earlier 'Associate' was the term used in the Competency Standards.
3 Friedman (1999) quotes an advertisement by Merrill Lynch in the newspapers in the USA in October 1998: The World Is 10 Years Old. It was born when the Wall fell in 1989. It's no surprise that the world's youngest economy - the global economy - is still finding its bearings. The intricate checks and balances that stabilise economies are only incorporated with time. Many world markets are only recently freed, governed for the first time by the emotions of the people rather than the fists of the state. From where we sit, none of this diminishes the promise offered a decade ago by the demise of the walled-off world . . . The spread of free markets and democracy around the world is permitting more people everywhere to turn their aspirations into achievements. And technology, properly harnessed and liberally distributed, has the power to erase not just geographical borders but also human ones. It seems to us that, for a 10-year-old, the world continues to hold great promise. In the meantime, no one ever said growing up was easy.
4 These ideas draw from reviews of What Engineers Know and How They Know It: Analytical Studies from Aeronautical History by Vincenti, Johns Hopkins U Press. The first is by John Staudenmaier, SJ, professor of the history of technology at the University of Detroit Mercy, in Technology Review, July 1991. The second is by David F. Channell, Program in Historical Studies, University of Texas, in Science, Vol 253. 2 August 1991.
5 Estimate for engineers updated from Rice and Lloyd (1991) in Chapter 14. The estimates for other occupational groups are extrapolated by M R Rice from Census data.
Chapter 2
The Beginnings to 1919
By Brian E Lloyd
Engineering Formation and Education
This chapter examines how engineering education began and traces the development of the Australian profession up to the formation of IEAust. There was little engineering in the Australian colonies until the gold rushes in the 1850s, but engineering became a significant occupation after about 1860. Gold brought people and riches, stimulating development beyond the dreams of colonial administrators and pastoral settlers. Gold-seekers included relatively high numbers of professional men, artisans and clerks. The population of Australia grew from 440,000 people in 1850 to 3.8 million in 1901 and 5.4 million in 1920.

The early development of the cognitive base and social organisation of Australian engineering grew out of Britain and North America (Lloyd 1991.) After gold discovery, company mining and manufacturing, and engineering for roads, railways, water supplies and the telegraph system, created a demand for engineers. Early Australian civil engineers were formed by the British practice of pupillage training, and men who had served apprenticeships in England and Scotland trained apprentices in their workshops and drawing offices to form mechanical engineers. While these methods fulfilled most needs, they tended to create rigid mindsets, but there were a few who saw the need for education in engineering beyond experiential training.

During the 19th century engineering associations were devoted to disseminating knowledge, but membership numbers were small and admission criteria vague. The early associations did not provide a qualifying function nor assert control over the cognitive base of engineering or education. However, by the end of the 19th Century university and college educated engineers were gaining influence.

University Engineering in Melbourne and Sydney
The beginnings of engineering education in Australia was greatly influenced by the presence of well-educated men from Britain and Europe. It had elements of the first era of globalisation in an atmosphere of euphoria from the riches provided by gold. Engineering education at the University of Melbourne pre-dated all but a few engineering schools in Britain and Europe and the first Land Grant universities of North America. The University opened in 1855, when William Wilson (1826-1874) became Professor of Mathematics, fresh from his foundation Professorship at Queen's College in Belfast where engineering education began in 1850 as a 2-year diploma, converted to a BE in 1868. Engineering education began at Trinity College Dublin in 1842, with certificates in engineering until the first BE was conferred in 1872.

In 1861 the University of Melbourne introduced a 3-year full-time course for the Certificate of Civil Engineer (CE); a much sounder formation than pupillage. Students were few: the first graduate was William Kernot (1845-1909), with a BA in 1863, and a CE and MA in 1866. Some 30 CEs were completed by 1882. For 40 years Kernot was a major figure in engineering inside and outside the University. He became Professor of Engineering in 1882 and the Bachelor of Civil Engineering (BCE) 4-year full-time course began in 1883. The Faculty of Engineering was established in 1889. Table 2-1 shows how civil engineering developed in the period 1861 to 1918. Mechanical engineering began in 1907, and electrical engineering as a full course in 1911. An average of 10 engineers graduated between 1901 and 1919.

At the University of Sydney, established in 1850, the Challis bequest in 1880 funded the Faculty of Science with a sub-department of Engineering, with William Warren (1852-1926) as the first lecturer in 1883. Warren had served an apprenticeship in an English locomotive works and studied in Dublin and Manchester. He became Professor in 1884 and held the chair until 1925. His school was the first in Australia to engage in engineering research. By 1900 Warren's graduates totalled 64.

The 3-year Bachelor of Engineering (BE) had a core of mathematics and science, less emphasis upon surveying than at Melbourne, and options in the final year in civil, mechanical and mining engineering. A mechanical and electrical course produced the first graduate in 1895. The school produced some 285 graduates from 1901 to 1919. The BE in mechanical and electrical engineering became a 4-year course in 1900, and civil engineering became 4 years in 1910.
Technical Education

Engineering education in the technical colleges in Victoria evolved from the Schools of Mines opened at Ballarat in 1870 and Bendigo in 1873. In 1887 the Working Men’s College in Melbourne (WMC, later RMIT), the Gordon Technical College at Geelong, were founded. Single subjects were developed into courses for engine drivers and mine managers at Ballarat and Bendigo. Expert Certificates in engineering were awarded at Ballarat in 1872, WMC in 1894 and Bendigo in 1900, but numbers were small. Three-year full-time diplomas were awarded at Ballarat in 1897, WMC in 1903 and Bendigo in 1905. The courses were based on the Expert Certificate, with additional engineering and trade studies. The colleges were handicapped because students from elementary school were ill-prepared for tertiary studies. In 1898 the WMC instituted a preliminary year, extended to two years in 1909, and setting the pattern for junior technical schools. In 1919 admission required Year 9, (called the Intermediate Technical Certificate from 1924). Swinburne Technical College opened in 1915 and awarded diplomas in 1921. Engineering diplomas began in Geelong in 1917 and the first diploma was awarded in 1919. These colleges were managed by Councils, but those founded later were controlled by the Education Department, which from 1910 exercised curriculum control over all diploma courses. Footscray Technical College opened in 1915 and awarded diplomas in 1925.

The contrasting patterns of engineering education in Victoria and New South Wales represented the ends of the spectrum for Australian technical education. Technical instruction began in Sydney with classes in 1853 in the Sydney Mechanics School of Arts. The Sydney Working Men’s College was formed in 1878, and as the Sydney Technical College (STC), came under the Board of Technical Education in 1883, by which time there were courses for the Certificate of Industrial Expert. Between 1887 and 1895 students sat for examinations for the City and Guilds College of London, and by 1897 some 660 had taken these examinations in mechanical and electrical engineering. In 1889 the STC was transferred to the Technical Education Branch of the Department of Public Instruction. In 1892 the Certificate courses were replaced with 3-year part-time diplomas in civil, mechanical, electrical and mining engineering, but civil and mining were dropped by 1900. Admission was open to those who completed a trade course. The first Associateship Diploma (ASTC) was awarded in 1895. The college opened branches at Newcastle in 1895 and Broken Hill in 1898. Three-year full-time Diploma courses began in 1902 alongside the evening courses, but from 1915 all courses became 5 years part-time after completion of a trade apprenticeship or school Year 11. The first course in chemical engineering in Australia began at STC in 1915 and the first diploma was awarded in 1921.
**Engineering Education in Other States**

The Brisbane Technical College introduced 4-year part-time diplomas in 1911. The University of Queensland began engineering in 1912 and facilities for teaching civil, electrical and mechanical engineering were shared with the Central Technical College. The South Australian School of Mines (SASM) awarded the first 3-year engineering Associateships in 1890. In 1898 SASM and the adjacent University co-operated in courses for BSc and diploma awards in engineering. In 1907 the University appointed a professor of engineering and cooperation with the School continued: from 1911 students graduated from a 4-year course with awards of BE and Fellow of SASM. Those who took the course entirely within the School were Associates of SASM. Perth Technical College introduced full-time Associateships in 1909. The University of Western Australia commenced engineering courses in 1913 and the College vacated professional education in 1925 in favour of the university, substituting part-time para-professional diplomas. The University of Tasmania began engineering education in 1900 and, in cooperation with Hobart Technical College, offered engineering diploma courses in which the major subjects were taught by the University.

**Government Examinations in Victoria**

Government pupil training for engineers was reinforced in the 1880s by examinations for local government and, in Victoria, for water supply engineers. The system had begun in the 1860s for training Land Surveyors, and then for Municipal Surveyors (local government engineers). An example is provided by the first examination in 1887 for the Victorian Board of Examiners of Engineers of Water Supply (EWS): General Principles of Civil Engineering, Engineering Structures, Hydraulic Engineering and Surveying. Exemptions were granted for Members of ICE and graduates of the University of Melbourne. By 1899 the number of certificates awarded was 121, including 60 who completed one or more subjects. A similar examination for Municipal Surveyors covered Principles of Engineering Construction, Drainage and Sanitary Engineering, Road and Street Engineering and Surveying. Candidates had to serve articles for not less than 3 years under a civil engineer and have 3 years experience.

**The Engineering Work Force**

By comparison with larger industrialised countries, the number of engineers in colonial Australia was very small. In 1850 there were about 50 engineers in Australia. (Rice and Lloyd 1990 & 1991). By 1900 there were some 1050, including 250 with local university or technical college qualifications. Civil engineers predominated at about 56 per cent of the total number. They and telegraph engineers, about 13 per cent, were mainly employed in the public sector, while mechanical and electrical engineers were in private firms. About 21 per cent of the total were mechanical engineers. New graduates and diplomas in 1901 numbered about 25, increasing to 66 in 1919 and 144 in 1920 as returned servicemen resumed to their studies. In 1919, over half the engineer population of 2,400 had qualified from formal courses. By 1919 there were engineering schools in the six universities, but enrolments were small outside Sydney and Melbourne.

At the beginning of the 20th century the engineering-based work force comprised tradespeople and engineers, and between them people with a range of skills and education and a few with Expert Certificates. Trade courses of 3 to 4 years evening attendance gradually began in Victoria, but prior to 1914 there was no compulsion for apprentices to attend. In New South Wales 2 years of compulsory evening trade instruction began in 1909. Engineering Diplomas in NSW, entered from trade courses, were not regarded as professional qualifications.

At that time there was little recognition of the three elements of engineering role differentiation: specialism, field of practice (eg: design, manufacture, construction, operation, maintenance), and level of responsibility. Professor Kernot's typology from his Presidential Address to Victoria Institute of Engineers in 1907 described six roles that included engineers with degrees and diplomas:

A. Pioneer engineer, who lays out towns, roads and bridges.
C. Commercial engineer: engineer-manager running a foundry, fabrication shop or shipyard.
D. Managing expert engineer: head of the gas works, an electricity station, sewerage pumping station [eg: Spotswood for the Melbourne sewerage system], or head of a manufacturing establishment.
E. The engineer as a scientific referee, expert witness or consultant.
F. The engineer as an inventor.
Kernot's typology reflected Australian engineering at the beginning of the 20th Century: much in the public sector, most in small organisations where engineers were individual practitioners or managers. Diplomas were practical qualifications for managers or foremen, but not for consulting engineers. Some engineers in Sydney criticised the Technical College for usurping the work of the university instead of training apprentices. Such a view saw three categories: engineers, tradespeople with additional training to fit themselves as supervisors (ie: diplomates) and tradespeople. Even in 1920 the Handbook of Sydney Technical College described diplomas as covering the technologies of *trades*, but tending *slightly* toward a professional standard. That view changed after 1920 once IEAust recognised diplomates for professional status.

A discussion on engineering education in Melbourne in 1917 throws light on contemporary thinking. A utilitarian view from technical education epitomised the 'workshop culture', holding that university education was useful for *some* engineers, but many needed workshop experience not provided by the university. The 'workshop culture' held that if boys were kept at pure academic studies until the age of 18 years, they would evince a distaste for the everyday work of the *practical* engineer. If a boy did not enter the mechanical workshop before the age of 16, he would show a distaste for the *drudgery* of the workshop. Those views were criticised for mixing the education of an engineer with the training of a mechanic: did they really expect the 'practical engineer' to work with spanners and oil rags? The workshop culture persisted in the design of the diplomas of the Victorian colleges until the mid-20th Century.

The Engineering Profession

In the years after Federation there arose a desire for a unified and qualified profession to enhance the occupational identity and status of engineers. After 1910, as engineers with formal education began to predominate, the movement gained momentum through the small engineering associations in each State. Gradually the idea emerged of a need for a national, all embracing association to give engineers the power to address the issues of status and occupational identity. One of the earliest calls for unity came from James Alexander Smith in 1909. In 1912 John Monash and others caused VIE to prepare a plan for combining with other associations, but Monash's engineering career was interrupted by the 1914-18 war and he played no further part in these events. After the war a consensus emerged to form a national body. The first meeting of the Council in October 1919 marked the official foundation of the Institution of Engineers, Australia (IEAust).

Professionalisation was pursued by classification of IEAust members into grades. The IEAust defined the standard for engineering qualifications by creating its own examination in order to take the role of the qualifying association of professional engineering in Australia. New Associate Members, the first level of recognition as a professional engineer, had to be 25 years of age and 'trained' as an engineer, adequacy being expressed in terms of the IEAust examination, or possession of an exempting qualification from a university or a technical college. Professor Warren's Presidential Address in December 1920 brought together the issues that were to dominate the formative years: ethics, status, registration, education, and restriction of the term 'engineer' to the profession. The IEAust quickly established the standards and boundaries of Australian engineering, as demarcated from metallurgy, architecture, chemistry and physics.

Conclusion

By the beginning of the 20th Century, as Federation changed the colonies into the States of a unified nation, professionalisation in Australian engineering became identified with education. As the gold mining industry declined, other industries began to expand. The tragedy and heroism of World War I conferred a national identity upon Australia. The psychology of unity in diversity two decades after Federation saw three separate drives for a united and qualified profession of engineering: to unite engineers throughout Australia, to raise the status of engineers and differentiate them from manual workers, and the prescription of formal education as the primary criterion for professional engineering roles. The IEAust gave effect to these ambitions, but it took time.

Engineering education at universities and technical colleges was widely available by 1919, and the pupillage system was obsolete. With the influence of IEAust in gradually raising the standards of courses, by 1920 engineering education was on the threshold of a new era leading to nationally coordinated accreditation. The predecessor societies had taken no such role.
Chapter 3
Professional Consciousness: 1920-1979
By Brian E Lloyd

Status and Reward
This chapter considers Phase 2 of the development of the Australian engineering profession. It followed establishment of IEAust in 1919 to exercise occupational control and enhance the professional status of engineers. The IEAust accepted all those considered to be professional engineers, and then closed off the informal pathways by creating an examination as the primary criterion for admission to membership, and identifying exempting degrees and diplomas. Pupillage was finished. The new intellectual hurdle was not high, but IEAust also set about influencing the quality of engineering education. (See Lloyd 1991, Chapter 6.) Thus began definition of the profession by qualification: 'engineer' meant a person qualified for membership of IEAust. Lateral boundaries lay in the range of specialisms recognised as being part of engineering, and the vertical boundary lay in the level of intellectual attainment defined in the examination.

In the 1920s engineers were concerned that their education standards and the importance of their work should attract the prestige accorded to other professions. Many saw IEAust as the instrument for achieving material benefits flowing from professional status. A sense of identity and status-worthiness emerged as shared values in a non-systematic body of ideas, ideals, norms of behaviour and ethical values, some explicit and others informal, to sustain an overall orientation in the way engineers were to be organised and educated. The internalised drive for status and reward was accompanied by an externalised service motivation. The IEAust provided a national focal point for public activities of prominent engineer leaders, and became the coordinating instrument in industrial development as Governments looked to it for advice.

Uncontrolled use of the term 'engineer' had given rise in the United States to the title professional engineer. From the outset IEAust leaders spoke of 'professional engineers' as members of 'the profession of engineering'. At first IEAust tried to confine 'engineer' to those it recognised, by mounting a campaign for statutory registration. While the motivation included protection of the public, it was linked to a yearning for increased incomes and social status. But the quest for registration failed. Queensland was the only State to enact it, in a watered down form. In the mid-1930s acquisition of a Royal Charter added status to the Institution but contributed little to the social recognition or status of individuals.

While accepting the standards of the universities, the IEAust saw a need to lift the technical colleges out of the 'workshop culture', although demarcating professional from sub-professional occupations took another 40 years to achieve in the work place. A further element of identity was that engineers predominantly were employees rather than independent practitioners. The five elements of professional identity: occupational title, professional recognition, qualifications, level of income and nature of employment, all were important elements in subsequent historical developments. In the 1940s employee engineers organised to seek increased salaries through arbitration, eventually leading to success in the 1960s.

Table 3-1
Professional Engineering Labour Force 1920 to 1979 by Source of Qualification

<table>
<thead>
<tr>
<th>Year</th>
<th>Degree</th>
<th>Diploma</th>
<th>Immigrant</th>
<th>Pupilship/Examination</th>
<th>Total (Rounded)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1920</td>
<td>710</td>
<td>490</td>
<td>580</td>
<td>735</td>
<td>2,515</td>
</tr>
<tr>
<td>1929</td>
<td>1,440</td>
<td>920</td>
<td>435</td>
<td>880</td>
<td>3,675</td>
</tr>
<tr>
<td>1939</td>
<td>2,330</td>
<td>2,260</td>
<td>350</td>
<td>920</td>
<td>5,860</td>
</tr>
<tr>
<td>1949</td>
<td>4,000</td>
<td>4,600</td>
<td>240</td>
<td>920</td>
<td>9,760</td>
</tr>
<tr>
<td>1959</td>
<td>7,500</td>
<td>9,400</td>
<td>1,200</td>
<td>1,020</td>
<td>19,120</td>
</tr>
<tr>
<td>1969</td>
<td>14,000</td>
<td>15,000</td>
<td>6,000</td>
<td>970</td>
<td>35,970</td>
</tr>
<tr>
<td>1979</td>
<td>31,200</td>
<td>20,330</td>
<td>10,890</td>
<td>770</td>
<td>63,200</td>
</tr>
</tbody>
</table>

Professional Engineering Labour Force
In 1920 the Professional Engineering Labour Force (PELF) of 2500 engineers included some 60 per cent with university and college qualifications and 23 per cent recognised through pupillage or examinations. (Rice and Lloyd, 1990 & 1991). By 1979 the qualification mix had changed completely, as seen in Table 3-1. The proportion of engineers who had qualified from Australian engineering courses rose to 82 per cent, those formed through pupillage or examinations were 1.2 per cent, and the small contribution from...
examinations had ceased. By 1979 PELF 25 times that of 1920. In 1920 there were 464 professional engineers of working age per million of population, and nearly ten times that in 1979. The balance between engineering specialisms changed: mechanical engineers rose from 19 to 24 per cent, electrical engineers barely changed, while civil engineers fell from 50 to 34 per cent of the PELF. In 1979 some 17 per cent were in other specialisms.

The engineering-based industry before World War 2 operated in an environment of depression and low immigration. The structure of the work force continued to comprise three tiers: engineers, sub-professionals and tradespeople. The boundary between professional and sub-professional roles remained undefined in the work place, and there was very little provision for education specific to sub-professional roles. After the war there was an increase in demand for engineers in the manufacturing, process and infrastructure industries. Throughout the period to the mid-1960s some 60 per cent of engineers were employed in the public sector. By 1979 some 44 per cent of the PELF were so employed. After World War 2 increased activity in manufacturing and infrastructure development provided employment for engineers, boosted in number by the ex-servicemen resuming studies and by immigration. Graduations peaked in 1952 with over 500 from universities and 580 from colleges, compared with an average before the war of 100 and 150 respectively. The PELF almost doubled each decade from 1939 to 1979.

The IEAust Examination

The IEAust examination in the 1920s required candidates to pass the Examination or possess an exempting qualification, be at least 25 years of age and have 3 or 4 years experience excluding apprenticeship, pupillage or training. The Board of Examiners, for many years comprising Sydney-based engineers in, set the examination as the yardstick by which educational courses were judged. (The Board became the Accreditation Board in 1987.) The examination, illustrated in Figure 3-1 and unaltered for 30 years, reflected the needs of a remote colonial outpost with little industry and in transition from pupillage. Applicants who completed the Preliminary Examination or Leaving Certificate took the 5 papers in Sections A and B. With no test of mathematics beyond school level, there was little expectation of higher level qualitative expression or analysis.

<table>
<thead>
<tr>
<th>Preliminary Examination</th>
<th>Section B (With Intermediate or Junior Public Exam)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Section A</td>
<td></td>
</tr>
<tr>
<td>1. English, Geography, History</td>
<td>1. English, History, Geography</td>
</tr>
<tr>
<td>2. Arith, Geom, Algebra, Trig</td>
<td>2. Two papers: Algebra, Geometry, Trigonometry, Mensuration</td>
</tr>
<tr>
<td>3. One (after 1925): Chem; Physics, Geology</td>
<td>3. Geometrical Drawing</td>
</tr>
<tr>
<td>4. One (after 1925): Chem; Physics, Geology</td>
<td>4. One (after 1925): Chem; Physics, Geology</td>
</tr>
</tbody>
</table>

**Associate Membership Examination: Section A**
Mechanics and Materials of Construction
One from: Theory of Structures, or Electricity & Magnetism or Heat Engines
One from: Engineering Surveying, Hydraulics, Geology & Mineralogy, Stability and Resistance of Ships, Thermo & Electric Chemistry, Industrial Chemistry, Metallurgy, Other approved subject

**Associate Membership Examination: Section B:** A practical paper related to work experience, or a Thesis demonstrating a sound knowledge of engineering work. It could describe actual work undertaken.

*Figure 3-1 Structure of Examination of IEAust in 1922*

Because no government would enact laws excluding those previously accepted as engineers, in the drive for laws for registration IEAust avoided accusations of exclusivity by stating two principles in 1926 in a strategy of compromise: assurance to the public of the high (sic) standard of the qualifications, and providing accessible pathways from trade level through evening or private studies for the Examination. Control of standards through the examination was advocated on social equity grounds. While the standard was slight, it was high in relation to pupillage. But the expectation of disadvantaged aspirants being capable of undirected private study was unrealistic: between 1922 and 1927 only 26 passed. After 1925, Section B of the Preliminary Examination, set at university entrance level (Year 11), became the criterion for Student membership.

The identification of qualifications exempting from the examination marked the beginning of accreditation. The list of exempting qualifications for 1921 indicates the magnitude of the task in assessing the merits of the diverse existing offerings. The general formation routes at the time are illustrated in Figure 3-2. In 1925 IEAust required diploma entry level to be not less than School Intermediate. In New South Wales from 1923 the level was Leaving Certificate including English, mathematics and physics, or
Engineering Formation in the 1930s

Upgrading the examinations continued, but without change in the mathematics component until 1938 when the rules stated: 'Although no paper on mathematics is included in this examination, candidates will be assumed to possess an elementary knowledge of differential and integral calculus and of coordinate and solid geometry.' There remained lingering sympathy for the disadvantaged: in 1938 only 13 completed Section B and 9 in 1939. The rationale by then was concern for candidates in remote areas, naively expressed as admiration for the sterling qualities of persistence more essential to success than possession of knowledge.

In the period before World War 2 the standards of the diploma courses in NSW and Victoria gradually increased, but the Victorian Technical Education authorities still defended the workshop culture. There was also a welfare argument: the diplomas provided upward social mobility for people unable to gain entry to engineering via the university. This reflected the prevailing IEAust view of the three routes to the engineering profession: (a) practical 'training' and part-time evening study or correspondence, (b) ‘training’ at technical colleges through diploma courses, or (c) full-time university degree courses. In emphasising 'training', the concept of 'education' did not figure in prerequisites for professional recognition.

The prevailing view in the 1930s still was a work force of engineers and tradespeople, although qualified engineers and unqualified people employed in drawing offices often were designated as 'draughtsmen'. The first attempt to define a structured system of roles coupled to education came from Frank Sublet in 1936, (Sublet 1936) criticising the IEAust for setting low standards of professional engineering education; overlaps between the universities and technical colleges; and neglect of a level between the trade and the professional. His definitions of work functions involving workshops and machines envisaged six work-force categories:

**Trade Schools:** for categories 1 and 2:
2. Foremen and Overseers: more advanced training plus organising abilities and a sense of responsibility.

**Technical Colleges:** Providing full and part-time education in materials, drawing, production processes, machine tools, testing and supervision, but not design, and a practical vocational rather than professional ethos. Lower level courses would prepare others for foremanship roles.
3. Production Managers: supervise production or workshops, training in theory and engineering drawing.
4. Technical Assistants: repetition work for completion of designs, such as in drafting and electrical testing.

**Universities:** Professional education, and practical experience following undergraduate education.
5. Engineering Practitioners: theoretical worker seldom called upon to develop a fresh field in engineering; occupied with design and practice either under general direction or in accordance with precedent.
6. Engineering Leaders: a small class producing new lines of constructive thought; researchers, designers, chief engineers of large departments or managers, all involved in breaking new ground.
Sublet's efforts were pioneering, but his preoccupation with the status of university graduates may have caused others to fail to grasp the import of his analysis. He accurately forecast evolution in the work force, but he failed to separate the horizontal career progression element in his perception that the foreman needed higher level trade training. This is further discussed in Chapter 6. A reason for neglect of his analysis was the absence of any perception of a need in the work force to differentiate professional and para-professional roles.

A survey of IEAust members in 1937/8 brought responses from half the profession and showed that the public sector constituted 60 per cent of engineering employment. Civil engineers represented 57 per cent of the total, and 80 per cent of them were in the public sector, as were 60 per cent of electrical engineers, while 60 per cent of mechanical engineers were in private firms. Some 68 per cent of engineers were under 40 years of age. Engineering was conducted in the following categories:

Public Sector: Federal: Defence, Aviation, Construction, etc, and Instrumentalities: PMG, Snowy, etc. Defence Forces and support functions.
State: Works, Health, etc, and Instrumentalities: Electricity, Gas, Water, Transport, etc.
Local Government Councils.
Education (Universities, Technical Colleges becoming CAEs, TAFE).

Private Sector: Large companies and corporations, small companies employing a few engineers each. Consulting firms: Principals and Employee engineers.

It is no surprise that engineering was imbued with a public-sector ethos.

Status and Remuneration

The IEAust policies on qualifications and education were crucial to the developments in the 1940s and 1950s in the arbitrated resolution of salary levels for professional engineers. By the beginning of World War 2, Australian engineering was displaying many of the characteristics of a profession, as more than 90 per cent of engineers were qualified from formal courses or examination, but there was little occupational differentiation between engineers, draftsmen and non-qualified persons acting as engineers, and salaries were depressed.

The early war years diverted attention from the social movement that began in the 1930s, but by 1943 people were looking ahead to a better world. It was argued that without reasonable salaries, status could not be achieved, and without reasonable status, the social contribution of engineers would be stunted. Engineers were restive and their plea was clear: IEAust had to represent employee engineers on salaries. The Council got the message. In 1945 they enunciated the principle that corporate membership of IEAust was the criterion for full recognition as a professional engineer, thus creating the foundation for all that followed. (Lloyd & Vines 1996).

The Royal Charter was not a bar to participation in industrial arbitration matters, but the IEAust included employers while all members of an industrial association had to be employees operating under democratic rules conforming to the requirements of the Arbitration Act. There was no precedent for an independent association exclusive to professional people, but IEAust endorsed registration of the employee-based Association of Professional Engineers by the Arbitration Court. The APEA came into being in 1946. After lengthy opposition from industrial organisations claiming to represent engineers, APEA was registered for all areas of engineering employment. At that time the professional engineering labour force was nearly 9,000, IEAust membership included some 5,000 employee engineers and APEA had grown to 900 members. By 1950 APEA was the focus of the quest for status derived from increased reward.

Clearing the Decks on Professional Identity

During the 1940s and 1950s several developments clarified the identity of engineers. A need to upgrade courses was recognised, and proceeded as described in Chapter 4. In 1952 IEAust introduced an expanded syllabus for the Examination. Section A comprising papers on mathematics, applied science and engineering drawing. Section B comprised papers on engineering applications. In 1956 the pass rate in the more arduous examination was about 20 per cent. By contrast under the old syllabus, 75 passed out of 171 in Section B in 1955. But the days of cadetships and private study for the examination were over: the rules were changed to admit only those who could not attend a course leading to complete or partial exemption. In 1955 the PMG Open Examination was abandoned. In 1958 local government examining
bodies complied with the new syllabus for the small numbers presenting for these examinations. The IEAust ceased to conduct the Associate Membership Examination after 1970 and the remaining government examination was abolished by 1975.

During the early period the distinction between professional and non-professional work was not explicit, and the Junior grade in IEAust compounded this confusion: it denoted either a quasi-professional state while preparing for the examination, or a qualified engineer gaining experience for Associate Membership. Work experience (stated as 'professional' experience) was a prerequisite of the Associate Membership Examination. Some applicants were admitted conditionally as Associate Members subject to passing the examination. In 1951 a new grade of Graduate provided for qualified engineers as a precursor to Associate Membership, and the Junior grade was phased out. Grades then became: Member and Associate Member for corporate members, Graduate for qualified engineers not yet corporate members, and Student and Associate for non-engineers. The changes clarified professional identity.

Definition by qualification, as distinct from definition by function, was an important issue in IEAust. In 1953 the European and United States Conference on Engineering Education formulated functional definitions for 'engineer' and 'engineering technician'. In 1954 the Commonwealth Engineering Conference adopted the definitions subject to ratification by the participating institutions, but IEAust rejected them. This was consistent with the 1945 resolution of the Council mentioned above, and a vital feature of the Professional Engineers Case. As immigration became a significant factor after World War 2, the criterion for IEAust recognition was qualification. With increasing immigration and a shortage of engineers, employers looked to IEAust for assessment of qualifications: this was tantamount to issue of a licences to practice.

Professional Engineers Cases
While these developments were taking place in education and professional identity, the leaders of APEA gained experience, suffered disappointments and finally mounted a national case for the valuation of professional engineering work. When the Case was launched at the end of 1956, membership of APEA stood at some 3,600, nearly one quarter of the professional engineering labour force. Definition by qualification was a threshold issue. Definition of the profession by functions performed had been tried in the USA in the 1950s in the Taft Hartley Act, intended to protect the status recognition of professionally qualified people. However, it backfired when the courts found that when a person demonstrated capabilities in professional functions (albeit in a limited fashion) they had to be accorded professional status (See O'Dea 1965).

The claims lodged by APEA included definitions that relied upon IEAust qualifications at two points: Qualified Engineer without experience, and Chartered Engineer, corresponding to corporate member of IEAust. The salary claimed for the Chartered Engineer was some 50 to 60 per cent above the current paid salary rates.

The hearing began in 1957 against fierce legal opposition that challenged definition by qualification. That question was resolved when the High Court accepted that the functions undertaken in employment as a professional engineer were described unambiguously in terms of the qualifications needed to carry them out. This concept, breathtaking in its simplicity, was crucial.

The case for increased salaries commenced in September 1959 with evidence on engineering education and the differentiation of professional engineers from other work force categories. This evidence, and much other evidence on the work value of engineers, was not contested. After strenuous legal argument against the idea of an award for professional engineers, especially from the States Governments, the decision came in June 1961. The Commis-
sion gave legal backing to the role of IEAust in occupational delineation, but did not accord monopoly in terms of requiring membership. The new term ‘experienced engineer’, essentially the same as 'chartered engineer', confirmed the IEAust practice as follows:

**Experienced Engineer:** a person not less than 25 years, requiring formation as:

(a) Associate Member of IEAust, having:

(i) 4 or 5-year degree in engineering and 3 years professional experience; or
(ii) a shorter degree, a diploma, or other, and 4 years experience; or

(b) If not a member of IEAust:

(i) 4 or 5-year degree in engineering and 4 years experience; or
(ii) a shorter degree, a diploma, or other, and 5 years experience.

These provisions are made clear by reference to Figure 3-3, depicting the educational and professional formation of graduates and diplomates in Victoria and Queensland. The Commission created a financial incentive to join IEAust: in each pathway, those who became Associate Members of IEAust had a one year salary increment advantage. The full-time diplomate became a Qualified Engineer one year earlier than the graduate, and the salary set was one increment below graduate, but both reached Experienced Engineer at 25 years of age if they became corporate members, and 26 if they did not. In June 1962 the Professional Engineers Case No 2 established salary standards for responsibility levels above Experienced Engineer, later adopted throughout the public sector and providing guidance for the private sector. By 1979 APEA had over 15,000 members and achieved much of what it had set out to do. The standard of living for engineers was much improved. Recognition of engineering as a profession was defined in terms of the qualifications, and clearly differentiated from para-professional occupations.

In 1991 APEA with 16,000 members merged with the 800 strong Association of Professional Scientists of Australia, to become APESA. This body became the Association of Professional Engineers, Scientists and Managers Australia (APESMA) following further amalgamations to cover architects, managers, pharmacists and railway professionals. Membership was some 25,000 in 1999 and was increasing by an average of 5% per annum.

**Accreditation of Engineering Courses**

During the late 1950s the membership of the Board of Examiners was democratised to include representatives from the technical colleges, and the evidence presented by APEA in 1958 for the first time threw light on the national system of engineering education. Three policy statements by IEAust in 1958, 1961 and 1967, *Basic Requirements, Standard of Entry, and Minimum Length* for engineering courses, marked the beginning of the new era in the accreditation of courses. The statements confirmed IEAust as the body setting professional standards, and the Arbitration Commission gave substance to that claim in the Professional Engineers Awards.

In the *Basic Requirements* statement, 'humanistic and economic' studies, and 'narrow specialised fields' were viewed with suspicion. There was an unspoken hope that technical college diploma courses would go away, so the 4-year degree would be the norm. The next step in 1961 required that the standard for admission to engineering courses be completion of secondary education: as from 1971 courses had to be not less than 3 years full-time or 5 years part-time after the general standard of matriculation.

In 1966 Federal Government policies on tertiary education included support for 3-year diploma courses, but in January 1967 IEAust issued a statement 'The Minimum Length of Engineering Courses', requiring that from June 1980 admission as a Graduate would require 4 years full-time education or the equivalent: the '1980 Rule'. Noting Government support for 3-year diplomas, IEAust held that professional recognition was the business of professional bodies. However, the 1980 Rule was not justified by cogent educational argument and it was said by critics to be inspired by status rather than educational need.

Displaying incredible naivete in the light of the philosophical outcomes of the Professional Engineers Case, the IEAust accepted continuance of 3-year engineering courses that after 1980 would be recognised by IEAust as professional engineering qualifications. The Institution tried to sidestep the industrial relations question: what of the occupational identity of post-1980 diplomates? While there is no direct evidence of a plan for quasi-professional diplomates to subvert the APEA awards, there was no consultation with APEA either. While there was no opposition to the 1980 Rule on educational grounds, it was clear to APEA that continued existence of diploma courses would undermine the role of IEAust as
the custodian of the professional identity of engineers because the diplomates would continue to be employed as engineers. Elimination of 3-year courses after 1980 was vital, despite IEAust indifference.

Engineering was considered the most pragmatic of all professions, but there was pragmatism on all sides concerning 3-year courses. Those outside the engineering profession who favoured retention of 3-year courses did not attempt to justify their stance on educational grounds. For APEA, the imperative of a clear occupational identity overrode all other considerations in the need to eliminate the diplomas.

In the end, following pressure emanating mainly from APEA, all 3-year professional engineering courses ceased soon after 1980. Some participants in the debates realised that after a decade or so, 3-year courses could be re-introduced for an occupation differentiated from 'engineer'. In 1989 IEAust welcomed Engineering Technologists and the development of 3-year degrees for them.

Conclusion
After more than a century of tremendous change, in 1980 engineering became a 4-year degree-entry profession. Definition by qualification delineated professional engineering work. Industrial relations delivered professional recognition and salary levels. Two factors were crucial: the engineering profession had its educational house in order and the profession could be defined by virtue of its knowledge base. Furthermore, IEAust had eliminated the last ties with pupillage.

The IEAust was accepted as the professional body responsible for qualifications. By placing IEAust criteria into the award definitions, corporate membership was confirmed as the hallmark of responsible practice. However, the legal standing of Professional Engineers was not in terms of licensing practice, but simply as to the criteria for professional standing. The Commission recognised engineering as a profession on the basis of its qualifications, the importance of its work and its national character. The long-term outcomes were confirmed occupational identity and raised status for engineers. APEA became a force, in partnership with IEAust.

By 1979 the profession of engineering seemed to be in safe hands, despite the ineptitude shown by IEAust concerning the 1980 Rule in reaching that point. All remained well until the end of the century, by which time this history, and the professional imperatives concerning professional identity as recounted here, had been forgotten by the leaders of the profession.

This chapter has been about a profession finding its way: Chapter 15 describes a profession losing its way.
Chapter 4
Diplomas and Degrees 1920 to 1979
By Brian E Lloyd

Introduction
This chapter reviews the development of benchmark professional engineering courses during 1919 to 1979, as offered in NSW and Victoria, the two States educating 50 per cent of Australian professional engineers and 85 per cent of non-university engineers. In 1920 the courses of the technical colleges had not yet come under the influence of IEAust, therefore they illustrate educational practices at the end of Phase 1. Analyses show rising educational standards in the expanding body of knowledge of engineering under the unifying quality assurance of IEAust. The growth of specialisms offered at the end of Phase 2 is an indicator of the development of the knowledge base of engineering. There is an unbroken line in Victoria from the Diplomas of the Working Men's College (WMC) in 1920 to the BEng courses at RMIT in 1979. For NSW in the pre-1979 era, non-university courses were part-time under the centralised control of the Sydney Technical College (STC) and the same tradition informed the BE programs of the two lineal descendants: UNSW and the University of Technology Sydney.

Engineering Education in Victoria
In 1946 the University of Melbourne raised the degree admission standard from Leaving (Year 11) to Matriculation (Year 12), and the old individual degree postnominals such as BCE, BEE and BMechE were replaced in 1960 by the Bachelor of Engineering (BE). By the mid-1950s educationists had identified a practical limit to packing more facts into courses of traditional design, and the computer was becoming a factor of change (Lloyd 1968). The general approach in civil engineering showed little apparent change from 1918 (Chapter 2, Table 2-1) to 1958, and Lloyd & Wilkin (1962, pp. 161-70) describe the continuous increase in depth and analytical approach. The study of surveying was much reduced to enable greater attention to theoretical engineering studies. The 1961 course in electrical engineering remained much committed to mechanical engineering, but by 1979 the influence of mechanical engineering had diminished and electronics was beginning to take over, while electrical power engineering could be avoided after Year 3 and only minor power engineering were available in Year 4 electives.

The second university in Victoria, Monash University, was opened in 1961 and named after Sir John Monash who graduated BCE at the University of Melbourne in 1891. La Trobe University opened in 1967, and in the 1970s a Bachelor of Communication Engineering was offered as a 2-year program following a BSc, but this initiative was not a success.

The evolution of degrees alongside the college diplomas is illustrated in Figure 4-1. New diploma-teaching colleges were opened by the Education Department, at Caulfield and Preston, and other small Colleges at Castlemaine, Maryborough and Warrnambool also provided diplomas. The WMC became the Melbourne Technical College (MTC) in 1933, added 'Royal' in 1954 and became the Royal Melbourne Institute of Technology (RMIT) in 1967. The WMC increased the diploma admission requirement to Year 10 in 1923, but other colleges did not to so until 1936. Milestones are summarised in Figure 4-1, showing that by 1965 the nominal age at qualification from the Associateship Diploma was 21 years, whereas in 1920 it was 18 years. Major change began in 1965 when the Victoria Institute of Colleges (VIC) was established, and the nine Colleges of Advanced Education developed BEng (as distinct from BE) courses with VIC as the awarding authority:

- Ballarat CAE at Mt Helen and offered an integrated BEng in Civil, Mechanical, Electrical and Mining.
- The new Bendigo Institute of Technology, from 1976 known as the Bendigo College of Advanced Education, offered a diploma until 1980. A BEng Civil was accredited by IEAust in 1978, but it closed down in 1981.
- The higher education section of RMIT become a degree provider.
- In 1968 Gordon Institute of Technology moved diplomas to Waurn Ponds and introduced degrees in 1971. Deakin University was established in 1974 and took over the engineering courses, but in 1981 the Federal Government withdrew funding for engineering courses.
- Other colleges introduced engineering degrees: Footscray, Swinburne, Caulfield, Gippsland, and Preston. Diplomas at Castlemaine, Maryborough and Warrnambool ceased.
- Reorganisation during 1976-78 replaced the VIC with the Victorian Post-Secondary Education Commission (VPSEC), and colleges awarded their own degrees. At Preston, engineering courses ceased after 1980.
Development of Victorian diploma courses is illustrated in Figure 4-1. Diploma mathematics, physics and chemistry in 1920 were below tertiary level in courses approximating 1.5 years of practical post-school studies. The civil course included trade fitting and carpentry, and studies in structures, hydraulics, engineering drawing and surveying, but analytical treatment was limited. Electrical engineering included trade fitting, wiring, blacksmithing and patternmaking, and mechanical engineering and drawing practice overshadowed electrical studies. The level of mathematics imposed serious limitations on treatment of electrical theory.

By 1936 diplomas had been dramatically upgraded at the MTC, to provide a total school and higher education of 10 + 4 = 14 years by comparison with the University 11 + 4 = 15 years. Mathematics was extended in courses that were equivalent to about 2.5 years at post-Year 12 tertiary level. The education pathway for the diplomas in 1958 remained at 10 + 4 = 14 years, by comparison with the University 12 + 4 = 16 years. A revision in 1954 updated mathematics in courses of a little over 2.5 post-year 12 tertiary years. Civil had reduced surveying, while electrical still included a good deal of trade and mechanical work, but now included electronics.

The courses in 1967 represent the final phase of the Victorian diplomas. Total education became 11 + 4 = 15 years, by comparison with then Australia-wide university pattern of 12 + 4 = 16 years. Major changes were evident in electrical engineering, where the main thrust of electrical power was
augmented by 2 years of electronics and control systems but little trade work. A separate electronics course included communications and electronic design and omitted power engineering. The diplomas at RMIT averaged some 3100 hours at tertiary level, while other colleges averaged about 2700, but core studies in each specialism were the same. RMIT also offered a diploma in communications engineering and included the new study of computer programming, together with additional mathematics and engineering sciences. In about 1971 the courses were changed to 3 years full-time from Year 12.

The BEng 1979 at RMIT courses in exemplify the evolution of non-university degrees. By that time the Colleges exercised academic autonomy within two constraints: accreditation by VPSEC involving a committee of engineering practitioners and university academic engineers, and accreditation by IEAust by a different group of academic engineers and practitioners from outside the State. Diversity was encouraged, but great attention was paid to standards. The RMIT degrees extended studies in engineering sciences, applications and design, underpinned by advanced mathematics and computing. The scope of electrical engineering already had been extended into separate specialisms in electronics and in communications engineering, and the study of semiconductors was beginning to pervade courses. While the university academic years remained at 26 weeks, in the colleges the teaching year was 33 to 35 weeks. The 'lecture' approach in the university contrasted with a 'teaching' in the diplomas, the latter approach leaving less time for private studies and other activities. The 3000 tertiary contact hours in 3 years in the 1967 diplomas overloaded students. Degree studies at RMIT in 1979 still presented a formidable work challenge in that it involved 28 week academic years and weekly contact up to 26.5 hours. Two factors inhibited reduction: conservatism in the face of searching accreditation processes, and difficulties in adopting the university 'lecture' approach.

Engineering Education in New South Wales

In NSW professional engineering qualifications evolved from 1900 as 3-year part-time diplomas and 3-year full-time degrees, both following 11 years of school, to 4-year BE courses following 12 years of school, as illustrated in Figure 4-2. The Sydney Technical College (ASTC) courses developed in content and depth in ways that paralleled developments in Victoria. Courses were available in Chemical, Electrical, Telephone and Telegraph, Mechanical, Municipal, Sanitary and Mining Engineering. Almost the entire mathematics, physics and chemistry in the 1920 Diplomas were below tertiary level, but the part-time courses devoted no time to trade studies because students gained that experience in prior or concurrent employment. The civil engineering course was equivalent to about 2 years of practical and descriptive studies of infrastructure engineering accompanied by engineering drawing and some surveying. Electrical engineering was much the same as in Victoria with trade studies omitted, but the equivalent of some 1.5 years of practical engineering studies. The courses of 1948 represented a dramatic upgrade, and were typical of the last diploma courses in NSW. The whole course was at tertiary level, equivalent to a little over 2.5 years full-time study.

When the NSW University of Technology (UNSW from 1958) came into being in 1949 there was close cooperation with the Department of Technical Education. From 1950, one or two-year part-time courses allowed ASTC diplomates to obtain BE degrees, or to enter an ME program. In 1951 the university took over teaching the ASTC and revised and integrated the diplomas into 7-year part-time BE programs. In 1961 the Diplomas were replaced at UNSW with 6-year part-time BSc(Tech) courses as shortened versions of the full-time BE. The new approach changed the nature of part-time engineering education, giving much greater emphasis to mathematics and science. Civil engineering studies concentrated on structures, hydraulics and surveying. Electrical engineering was diverging into power systems, power utilisation and control, and communication engineering. In 1967 the Year 12 Higher School Certificate raised the entry standard for all engineering courses.

In 1979 the BE courses at UNSW are representative of degrees that emerged from the tradition of diploma teaching. While UNSW still offered parallel part-time degrees for BSc (Eng), by this time part-time education was more highly developed by the New South Wales Institute of Technology (NSWIT). Although para-professional certificate courses became a predominant mission for the Department of Technical Education in the 1960s, there remained a demand for diplomas. In 1965 the Department created the NSWIT to enrol students in new Diploma in Technology engineering courses of 5-years part-time with day-release over 36-weeks a year. The later BE courses in 1979 at NSWIT thus represented another direct evolution out of the diplomas. In 1971 the Institute extended the diplomas to BE. Incorporation under the Colleges of Advanced Education Act of NSW in 1975, NSWIT became
independent from the Department, to be governed along university lines. In 1987 the Institute was reconstituted as the University of Technology, Sydney (UTS). Courses were 6-years part-time or cooperative education. Part-time attendance required 12 hours per week in 12 semesters of 18 weeks. The cooperative course required 24 hours per week over six semesters of 18 weeks alternating with work periods. The courses were accredited by IEAust as fulfilling post-1980 requirements.

The Universities at Newcastle and Wollongong began as branches of the Sydney Technical College. In 1965 the University of Newcastle was formed, and BE courses were offered. At Wollongong from 1951, ASTC diplomas were offered by a Division of NSW University of Technology. The Division became a University College in 1961, and in 1975 it gained independence as the University of Wollongong.

Engineering Education in Other States
In Queensland in 1925 a Diploma of Civil Engineering was introduced initially to serve employees of the Irrigation Commission and the Department of Main Roads, and it was recognised by IEAust. Following formation of the Queensland Institute of Technology, in 1967 Fellowship and Associate Diplomas were offered in Brisbane, Rockhampton and Toowoomba. In 1971 independence was gained by each as Colleges of Advanced Education, and Bachelor of Engineering degrees began shortly afterwards. The University of Southern Queensland began as the Darling Downs Institute of Advanced Education, and the Central Queensland University began as the Queensland Institute of Technology Capricornia. James Cook University of North Queensland was established as a College of the University of Queensland at Townsville, enrolling the first students in 1961 and gaining independence in 1970. In 1971 the BE in Civil Engineering was accredited by IEAust, followed in 1973 by Electrical Engineering.

In South Australia, the Associateships of SASM described in Chapter 2 were discontinued 1950. The 5-year BE and Fellowships continued until 1957, when the Fellowship became a 3-year Bachelor of Technology awarded by the University but conducted by SASM. In 1960 the School was renamed the South Australian Institute of Technology (SAIT). In 1966, with the introduction of school Year 12, the
university BE was reduced to 4 years but the Institute retained the 3-year courses. In 1967 the Institute was designated a college of advanced education, developed a new site at The Levels for transfer of the technological departments out of the city, and the Bachelor of Engineering (BEng) became an award of Institute.

In 1944, at the request of the Federal Government, Perth Technical College introduced new professional Associateship courses. In 1966 these courses were transferred to the Western Australian Institute of Technology (WAIT), where BEng courses began in 1973. The small engineering school at the Western Australian School of Mines at Kalgoorlie continued to serve the mining industry with professional courses in mining and general engineering. In 1969 the WASM became a constituent of WAIT and offered BEng courses. The University of Western Australia BE courses were 5 years full-time until 1966.

In 1921 the University of Tasmania and the Education Department began the joint provision of diploma courses. In 1922 the University introduced BE courses, and diplomas and degrees were conducted under an Engineering Board of Management. In the 1960s the Tasmanian College of Advanced Education took over the engineering diploma courses, and later offered degrees, but engineering courses were closed down in 1977.

The Workshop Culture
Until 1958 Victorian diploma courses in electrical engineering and in mechanical engineering included significant trade level instruction. What might be the rationale for overburdening a professional electrical engineering course with the full range of practical skills of apprentice fitters and turners, and electrical mechanics? It is difficult to understand why the inclusion of so much practical detail persisted alongside a neglect of increasingly important studies in electronics. Were the course planners responding to demands from industry, or were they acting out a lingering misconception of engineers working as shop floor supervisors? The heavy trade content, a long overhang of pre-World War 1 workshop culture, was not supported by evidence in the Professional Engineers Case 1959-61 discussed in Chapter 3. Many witnesses showed that diplomates were employed alongside university graduates in professional engineering work in planning and design, and in the organisation and management of construction, operations and maintenance (Lloyd & Vines (1996), and Lloyd (1991)). There was no demand for trade skills.

The answer in 1958 must rest with the Inspectors of Technical Schools, who were the curriculum managers of the Department, and who exhibited a blind spot in relation to the realities of the work force that rarely placed even para-professionals in trade-related roles. The 1965 revision of diploma courses eliminated the problem, and by the end of the 1960s development of new para-professional courses began. It is likely that both were influenced by the light thrown upon professional engineering education and practice in the Professional Engineers Case.

Facing the Information Age
It is of interest to consider another gap between work-force reality and educational provisions for the light and heavy current strands of electrical engineering. The Australian universities, with their strong civil engineering culture, were slow to provide courses in electrical engineering, and professional education in telecommunications was inhibited by the limited number of engineers available as lecturers. The Royal Commission inquiry into the Post Office of 1910 exposed an urgent need for telecommunication engineers but the universities did not respond. Efforts by the Postal Department to foster correspondence study and recruit engineers in Australia were not successful, so internal training and recruitment from Britain provided the only resort (Moyall, 1984). During World War 1 the Postal Institute organised classes in telephone and telegraph technology and engineering drawing, and opened a route whereby technical staff could gain in-house training as fitters and mechanics. An experienced trainee with Leaving Certificate could take internal examinations in General Engineering and in one of Line Construction, Telegraph Equipment or Telephone Equipment.

In 1918, in connection with a salary case, T. H. Laby, Professor of Natural Philosophy at the University of Melbourne, investigated educational requirements in the Post Office, and found a need to broaden and deepen in-house formation (Barnes et al. (1959), Part 3) Laby's recommendations for base grade engineers sought half the subjects of the University of Melbourne BEE course, together with four specialised Departmental subjects, the total reaching about third year of the degree. For higher engineers
he recommended 14 out of the 21 subjects of the BEE, and added further studies in electricity and propagation theory, Telephone and Telegraph Engineering, and Generation, Transmission and Distribution of Electrical Energy. This was about equivalent to the BEE. Laby thus identified the body of knowledge needed for telecommunications engineers.

In-house Departmental courses and examinations continued. The diploma course in Telephone & Telegraph Engineering offered by the STC was listed as recognised qualifications by IEAust in 1934 to 1958. A Diploma in Communications Engineering commenced at the MTC in 1939, as the forerunner to a heavy commitment to this specialism at RMIT. In the post-World War 2 period the Department was critically short of engineers, and British engineers were recruited. A cadet engineer scheme was initiated in 1949 and in that year the University of Queensland produced graduates in communications engineering. By the mid-1950s other universities were offering electrical engineering degrees that included studies suitng communications engineering needs.

Mechanical engineering studies in electrical engineering courses had diminished considerably by the 1960s, by which time separate engineering specialisms in electronics and communications engineering were beginning the dramatic expansion of the spectrum of electrical engineering. The nature of electronics-based studies was changing beyond recognition: vacuum tube principles and discrete component circuitry, as the basis for electronics that had blossomed in the 1940s and 1950s, were overtaken by semiconductors.

**Conclusion**

It was clear by 1979 that the definition of electrical engineering had changed, and that integrated circuitry, digital electronics and computers were about to overshadow electrical power. Throughout the world electrical engineering education was entering the 'information age' of digital electronics and computers. This represents a circular shift over the century, from the beginnings of communications engineering in telegraphy. Electrical power engineering held sway for most of the period but by 1979 the circle was almost back to telecommunications.

In contrast, the classical definitions of civil, mechanical and mining engineering hardly changed, and a perception of civil engineers as surveyors persisted for many years. After World War 2 mechanical engineering branched into specialisms in manufacturing, and in fields related to transportation in the forms of aeronautical engineering and naval architecture. The early concentration on metallic materials was about to broaden into courses in materials engineering. Chemical engineering was established as a major specialism.

The other dimension of the definition of engineering lies in the intellectual standard of engineering education. This Chapter indicates the very considerable increase in the intellectual demands of engineering education from 1920 to 1979. Throughout the period the profession was defined in terms of the qualifications recognised by IEAust, and by 1980 a four year degree in engineering, or equivalent, was required for admission as a Graduate. Although at the beginning some existing engineering courses were excluded from IEAust recognition, by the end of the 1960s all professional engineering courses in Australia were subject to IEAust accreditation.

A striking feature of the analyses in this chapter is the contrast between NSW and Victoria in the evolution of engineering education. Western and South Australia developed on similar lines to Victoria, but without the decentralisation arising from the days of gold in Victoria. Queensland and Tasmania followed similar patterns to New South Wales, including the centralisation strategy in technical education. It was in NSW where the evolution from diplomas to degrees began. By 1980 engineering was a 4-year degree entry profession.
Chapter 5
Approaching the New Era 1980 to 2000
By Brian E Lloyd

Introduction
The year 1980 commenced Phase 3 of engineering, bringing change more extensive than in any previous period. The scene was set by IEAust in a statement Professional Engineering Education and Practical Experience (IEAust 1980), emphasising the responsibility of the profession to sustain an Australian technological capability, and the need for graduates with competence to contribute internationally.

The report expressing anxiety about a fall in the number graduates in the early 1980s, without acknowledging that the problem arose largely from application of the 1980 Rule. Australian resident graduates fell by some 25 per cent in the early 1980s (Rice and Lloyd, 1990). The annual number of Australian graduates fell from 2700 in mid-1970s to 2000 in the early 1980s. The statement emphasised that to optimise the contributions of engineers to Australian industrial capability, a well-trained technical work force also was essential. There was support for improved transferability from the work force to professional engineering education. In 1980 the IEAust thus covered many issues played out in the period to 2000.

The statement expressed concern about 'proliferation' of engineering schools in Victoria, the aim being to maintain standards as a priority over accessibility. These opinions reflected IEAust submissions to Governments in the 1970s. The Partridge Committee in Victoria recommended closure of several engineering schools, and perhaps the 1980 statement encouraged the Federal Government to do so. However, the 1990s saw the creation of several new engineering schools, and great increases in engineering graduates from a diversity of courses. Women engineers became a new force in engineering.

Articulated education and off-campus studies expanded access. New 3-year Bachelor of Technology programs for Engineering Technologists became available for school leavers and for mature age students seeking to upgrade from a diversity of educational backgrounds. The IEAust accreditation process was recognised internationally and revised to concentrate on outcomes and quality. However, the social revolution and globalisation were not foreseen, nor perceived by many engineers as these factors overtook and changed engineering employment.

Professional Engineering Labour Force
Between 1979 and 2000 the Professional Engineering Labour Force (PELF) more than doubled and there were significant changes in composition and age distribution, as shown in Figures 5-1 and 5-2 and Table 5-1. By 2000 Australian engineers with degrees, and migrant engineers who invariably had degrees, made up 91 per cent of the total, while diploma engineers were aging and decreased to under 9 per cent. Engineers formed through examinations almost disappeared, and overseas-qualified engineers were over 3 times the number of 1979.

While absolute numbers in all age groups increased as shown in Table 5-1, Figure 5-2 shows that the age profile showed an increase in older engineers. The year-on-year growth rate in the PELF decreased from 4.8 per cent in 1989 to 3.4 per cent in 2000. In 1979 there were about 4,400 engineers of working age per million of population, and 7,700 per million in 2000. The balance of specialisms also changed, as discussed in later chapters.
Social Change in Engineering

Much of the evidence in the Professional Engineers Cases during 1958 to 1962 was about the contributions of engineers in developing the infrastructure through public works and telecommunications, and State road, rail, electricity and water authorities. It has been suggested (Vines 1999) that much of the management skill of those engineering leaders was acquired through training and experience in World War 2. Through those skills the post-war engineers developed and managed their command-and-control civilian organisations with great success. The beginning of the paradigm shift in engineering that began in the late 1970s coincided with the retirement of post-war engineering managers.

The new generation of engineers had little intellectual formation in the management skills needed in the new world of accountability for financial and environmental issues. Autocratic approaches were inappropriate in a better educated and democratised community. Engineers were perceived as lacking the skills needed and many traditionally senior engineering positions were taken over by non-technical people. Vines (1999) quotes a notorious example of a Director of Engineering who was an accountant! The phenomenon became known as de-engineering, defined as:

De-engineering: the managerial approach whereby engineers are replaced in the management and leadership of professional engineering functions by non-engineers. De-engineering does not relate to general management roles not having a need for engineering qualifications.

A principal cause of this process was political intervention that brought reorganisation, fragmentation, redeployment, outsourcing, tendering for work, and new roles and new career directions for those engineers who were not displaced from employment. The changing social environment required a realisation that engineering is not an end in itself, but that professional engineers are employed to create and manage assets, products and services for economic and social purposes, and to facilitate the conduct of commercial, community and government functions. Corporate shifts from means to ends brought displacement for many engineers as a 'damage limitation' strategy to put a cap upon capital expenditure. Promotional opportunities for engineers were much diminished by reducing middle management and as equal opportunity ideologies eliminated occupation-specific qualifications. Similar 'rationalisation' flowed through private engineering-based enterprises. Concerns arose that de-engineering would impair the effectiveness of engineering work as ambitious engineers sought promotion in 'open-discipline' careers. Engineers had to equip themselves better to survive and be effective. For APEA, the magnitude of social change was beyond any remedies that might have been sought through industrial arbitration. Postgraduate education in management followed, as discussed in Chapter 12. In 1990 IEAust published the policy requiring 10 per cent of undergraduate studies in management.

Ideologies of Labour Market Flexibility

The trends in de-engineering were not identified at the time with the alarming viewpoint of Scherer in 1982 in his analysis of the labour market for engineers (Chap 5, Blandy & Richardson 1982) He asserted the prerogative of employers to make whatever distinction that suits them between 'professional' and 'sub-professional engineers' (sic). He regarded the Professional Engineers Award as an affront to the economic ideology of labour substitution, because the Awards 'prevented' employment of unqualified people, a strategy that in his view would enhance labour market flexibility. Clearly he had no understanding of industrial relations, and he avoided any consideration of the education needed for professional work. In criticising specialisation in engineering education, he neglected risks from incompetence arising from inadequate specialised knowledge. His views reflected ideological frustration with the very nature of professionalism.

In 1985 the Bureau of Labour Market Research, a Federal Government agency, published a report entitled The Labour Market for Professional Engineers. The BLMR echoed Scherer in asserting that

<table>
<thead>
<tr>
<th>Table 5-1</th>
<th>PELF in 1979, 1989 and 2000</th>
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<tbody>
<tr>
<td><strong>(a) By Sources of Qualification (Rounded)</strong></td>
<td><strong>Degree</strong></td>
</tr>
<tr>
<td>1979</td>
<td>31,200</td>
</tr>
<tr>
<td>1989</td>
<td>54,000</td>
</tr>
<tr>
<td>2000</td>
<td>98,800</td>
</tr>
<tr>
<td><strong>(b) Age Distribution by Cohort</strong></td>
<td>23-34</td>
</tr>
<tr>
<td>31,900</td>
<td>17,900</td>
</tr>
<tr>
<td>37,200</td>
<td>29,000</td>
</tr>
<tr>
<td>59,600</td>
<td>42,100</td>
</tr>
</tbody>
</table>
'professional engineer' embraced two categories: 'qualified professional engineer' and 'unqualified professional engineer'. It saw IEAust as a detrimental influence, and advocated 'training up technicians' as substitute engineers. The Report was an affront to professional values and integrity, and IEAust responded by commissioning the publication *Labour Market Roles of Professional Engineers* to counter it (Lloyd and Rice, 1986). In 1985 there was no ambivalence about occupational identity, as there had been in the IEAust as discussed in Chapter 3. In promoting labour substitution, the BLMR touched the profession on a sensitive nerve: the differentiation of engineers from persons without qualifications. But a grasp of the principles of occupational identity always was tenuous in IEAust as the leadership changed. This is considered further in Chapter 15.

**Work-force Categories**

Before the 1960s many employers made little or no distinction between professional engineers, sub-professionals or those with part-completed qualifications. After the Professional Engineers Award in 1961 the distinction was identified, and it was realised that professional salaries could only be justified if engineers could delegate appropriate tasks to adequately educated sub-professional people.

Technical education authorities began to increase the focus on education for sub-professional categories (Lloyd, 1984). Technical grade occupations were designated as 'sub-professional', until that term was discarded because it implied subordination. 'Para-professional', the term adopted after this, connotes 'working beside a professional'. While not denying that many such people have a boss who is a professional person, the term implies entitlement to status and recognition. In 1973 the IEAust and APEA assisted in formation of a national body representing para-professional people: the Australian Institute of Engineering Associates (AIEA). The IEAust statement of 1980 identified the categories in the work force as:

(a) Professional Engineers (4-year full-time degrees, or equivalent)
(b) Engineering Associates (2-years post school education, or equivalent)
(c) Technicians (post-trade or office or laboratory-related education and training).
(d) Tradespeople (having served apprenticeships and part-time trade education.)

In 1983 a joint statement from IEAust and AIEA, *Guidelines on Education for the Engineering Industry* defined a systems approach to roles and the education, and differentiated the vertical and horizontal dimensions of career progression discussed in Chapter 6. 'Engineering associate' gained currency for the para-professional category. In 1983 the first *Australian Standard Classification of Occupations* (ASCO) reflected IEAust definitions. There was further evolution in the late 1980s in response to the industrial relations agenda. A research study for development of articulated education for the engineering work force resulted in recommendations for a 3-year qualification between 2-year para-professionals and the 4-year professional engineers. The 3-year qualification was for a distinct professional category of 'engineering technologist'.

In 1990 IEAust supported Federal Government initiatives in restructuring industrial awards, and updated definitions for the professional and para-professional occupations and their education. In 1991 IEAust and AIEA merged, and created new IEAust membership grades for technologists and para-professionals. The IEAust supported articulated education, and assumed responsibility for qualifying standards, motivated, among other things by the need to:

- protect professional standards from the efforts of labour unions attempting to gain recognition of unqualified people as professionals;
- define education and roles for engineering technologists and para-professionals; and
- foster a systems approach in qualifications, occupational titles, work roles and competency standards.

The plan was published by IEAust (IEAust 1990a). Generically the word 'technology' distinguishes particular endeavours from science. When the occupational term Engineering Technologist emerged in Australia, it already was in use overseas in the occupational sense to differentiate engineering technologists and engineers. In 1997 the updated edition of ASCO reflected the IEAust definitions. It is evident that the segments of the work spectrum occupied by engineers, technologists and para-professionals that evolved over time will continue to change with technological and social evolution. The systems view is considered in Chapter 6.
Qualifications and Competencies
Towards the end of the 1980s the ideology espoused by Scherer and the BLMR arose in a different form in the labour unions and the Federal bureaucracy as a proposal to eliminate qualification barriers through competency recognition of unqualified people as engineers. The ideological stance was 'it is what you can do that counts, not what you know.' While that might be valid for unskilled workers, it has no validity for professional and para-professional occupations. The idea of competency obviously is coupled to performance of work, but it cannot be decoupled from the knowledge required for the acquisition and demonstration of work competences.

The IEAust took control of the competency agenda and developed, with Government support, the National Competency Standards for Professional Engineers, published in 1993. The Standards, incorporating definitions by qualification and by function, were adopted by Governments, unions, employers and regulatory authorities. Further Standards on the same lines were developed for Engineering Technologists and Engineering Associates. (See Chapter 9.) Had IEAust stood aside it is likely that 'standards' would have been formulated for 'engineers' based on lists of functions performed, without reference to underpinning knowledge or qualifications. Had such definitions gained legal effect through industrial awards, without the essential element of definition by qualification, such standards would simply have been words to be misapplied by anyone motivated to do so.

The standards for the three occupational categories were revised and updated in 1998 in a single publication to include coordinated functional definitions backed by benchmark qualifications. Their primary purpose was for assessment of experiential development in one of the occupations after qualifying for the occupation, for recognition either as a Chartered Professional Engineer, or a Chartered Engineering Technologist or a Chartered Engineering Officer (Associate). The essential elements are the qualification, experiential development in work requiring such qualification, and evaluation against the Competency Standards Stage 2 for the occupation concerned.

A minor secondary purpose of the new Competency Standards was to provide yardsticks for assessment of experiential formation and development for the very few people who might attempt competency-based occupational articulation to Engineer from Technologist, or to Technologist from engineering para-professional. For validity, such assessment must include evaluation both of knowledge equivalent to the benchmark qualification for the higher occupation, and of experiential development in work applying such knowledge, evaluated against the Competency Standards for the higher occupation. No such assessments were ever applied in a complete form to provide confidence in valid outcomes.

The idea of 'competency standards' and the associated assessment procedures have little to do with undergraduate education, which provides the intellectual tools for competent performance after qualification. Chapter 9 considers the historical background.

Employment Change
The number of engineers employed in the public sector as a part of the PELF was an estimated 28,000 in 1979 and some 30,000 in 1989. During the 1990s much changed: in the federal sphere there was privatisation of defence industries, public works, telecommunications and airlines. In Victoria there was privatisation of electricity, gas and rail transport and rationalisation of water and local government; in South Australia there was outsourcing of water, and there also were significant reductions in public sector employment other States. The estimated net effect was to reduce public sector employment of the PELF to some 21,000 engineers, a decline from 44 per cent of the PELF in 1979 to 17 per cent in 2000. These estimates were based upon Rice and Lloyd (1991) in consultation with APESMA. In that period therefore, the PELF in the private sector rose from 32,000 to 126,000 engineers. Thus, while public sector employment was drastically reduced in numbers, the employment of professional engineers in a variety of roles in the private sector increased fourfold.

Major changes in the nature of professional engineering employment that began in the 1980s accelerated in the 1990s. Research on education and human resources in the water industry in 1979/80 by Lloyd & Nevill (1981) foreshadowed dramatic change:

- Past preoccupation with construction and water quantity was shifting to social issues, with changed community values and new corporate strategies on operations, asset management and water quality.
- Past rapid expansion was changing to a future of little growth, requiring restructuring and redeployment within a work force that would decrease in numbers.
The research found that future employment for graduate civil engineers would be reduced, but there would be opportunities in electronics and computer areas. Less design and construction would reduce initial experience for graduates, but some new graduates would be needed to secure leadership succession. Such graduates would best come from education attuned to managerial, investigational and operational functions.

A high proportion of the existing professional work force would need to have their initial education supplemented and broadened through postgraduate studies, especially in management. These findings were not popular among an engineering leadership imbued with the construction ethos, but in the subsequent 20 years change was profound. Large centralised water instrumentalities were dismembered and elements corporatised in the name of 'competition'. Outsourcing design and construction eliminated corporate memories, but in the water industry these major upheavals were not generally accompanied by privatisation of core functions.

In the electricity industry and sectors of public transport, particularly in Victoria, change was accompanied by privatisation. The Victorian electricity provider had been a vertically integrated system with engineering coordination of thermal, hydro and gas generation with transmission and distribution, for optimal long-term costs and conservation of resources. In the new model, central engineering design was disbanded and competition raised barriers against technology transfer between the several competing companies. Long-term engineering planning was replaced by a search for short-term commercial advantage. Integrated resource planning was replaced by reliance upon artificially regulated market responses and economic models.

These examples typify changes throughout the utilities sector. The ethos of engineering in the corporatised and privatised utilities was shifted from service and public good, to commercial decisions and shareholder benefit. A new paradigm of engineering emerged, heavily overlaid with commercialism and economic rationalism, as discussed in Chapter 15.

As economic rationalism and labour market flexibility were imposed upon the work force, the leadership of IEAust seemed to be unaware of the effects on the lives of members. Engineering education too was slow to respond to the changed nature of engineering practice. By 2000 the message of change had been received in some engineering schools where the teaching of management to undergraduates helped to prepare them for the new world. Other engineering schools stayed with tradition, despite messages coming out of reviews of engineering education.

**Engineering Education**

In 1986-88 a Review of the Discipline of Engineering (Williams 1988) was carried out under the aegis of the Commonwealth Tertiary Education Commission. The review committee, chaired by Sir Bruce Williams (an economics academic), and including engineering academics and two engineers from industry, reviewed professional engineering education and research in the light of industry and community requirements.

The general conclusion was that the good system could be made even better. Some deficiencies identified were: too little investment in modern equipment, engineering schools paid too little attention to retention rates, communication skills of students needed attention, engineering schools were showing insufficient interest in the human component of engineering practice, there was a need for greater emphasis on cooperative research with industry, and there should be better interaction between employers and engineering schools.

In 1995-96 a national Review of Engineering Education was chaired by Professor Peter Johnson (an architect), and a Steering Committee with representation from IEAust, the Australian Council of Engineering Deans, the Australian Academy of Technological Sciences and Engineering, the Department of Employment, Education Training and Youth Affairs, the Metal Trades Industry Association, APESMA, and others.

The report *Changing the Culture, Engineering Education into the Future* (Johnson 1996) expressed concern at the narrow focus of many engineering courses, and recommended a broadened approach to professionalism and social responsibility as well as technical excellence.

Cuts in funding affected viability and innovation in engineering schools, as well as educational standards. Evidence supported diversity: some courses should emphasise engineering science to high standards, and others should give greater attention to engineering practice. Collaboration between schools and with industry was essential.
Education for the Engineering Work Force

The foregoing review identified the need for review of education for other categories in the engineering work force, conducted under a small steering Committee chaired by Dr Sandra Humphrey (an educationist) and comprising representatives from education and industry. The report Beyond the Boundaries: Education and Training for the Engineering Work Force (1998) reviewed initial education for Engineering Technologists and para-professionals, but the focus was broad. The Report was cavalier in use of 'engineer' in several places to embrace engineers, technologists and associates: this was unforgivable in a publication of IEAust. Surveys indicated that each category needed education in business, communication and management, as well as technical knowledge and skills. Overlaps were identified between work-force roles, and a continuum of education was identified across technical and further education (TAFE) and the universities. The implication was a need for effective articulation opportunities in education.

For employers, membership of a 'professional' body was important in recruitment but not in promotion, and more important for engineers than for technologists or para-professionals. Qualifications were important in recruitment and promotion. Many employers looked to IEAust for assurance of the standard of overseas qualifications. The review recommended attributes to be developed in initial education for technologists and para-professionals, as summarised in Table 5-2.

Table 5-2
Attributes for Engineering Technologists and Engineering Para-professionals
As recommended in: Beyond the Boundaries (1998)

<table>
<thead>
<tr>
<th>Engineering Technologists</th>
<th>Engineering Para-professionals</th>
</tr>
</thead>
<tbody>
<tr>
<td>• adapt to the social, cultural, global, environmental and</td>
<td>• apply knowledge &amp; experience in social, cultural,</td>
</tr>
<tr>
<td>business contexts, including entrepreneurship, innovation,</td>
<td>global, environmental &amp; business contexts.</td>
</tr>
<tr>
<td>and sustainable development.</td>
<td>• apply knowledge of basic science, engineering and</td>
</tr>
<tr>
<td>• apply knowledge of basic science, engineering and</td>
<td>technological principles and techniques;</td>
</tr>
<tr>
<td>technological fundamentals;</td>
<td>• technical competence in at least one engineering</td>
</tr>
<tr>
<td>• communicate effectively within the engineering work force</td>
<td>discipline or field;</td>
</tr>
<tr>
<td>and the community;</td>
<td>• communicate effectively within the engineering</td>
</tr>
<tr>
<td>• in depth technical competence in a specialism or a</td>
<td>work force and the community at large;</td>
</tr>
<tr>
<td>technology; or broadly across a number;</td>
<td>• understand innovation in engineering business,</td>
</tr>
<tr>
<td>• understand innovation in engineering business, including</td>
<td>including factors critical in a global market;</td>
</tr>
<tr>
<td>factors critical to success in a global market;</td>
<td>• function effectively in multi-disciplinary and multi</td>
</tr>
<tr>
<td>• problem identification, formulation and solution;</td>
<td>-cultural teams;</td>
</tr>
<tr>
<td>• a systems approach to design &amp; operations;</td>
<td>• contribute to problem identification, formulation</td>
</tr>
<tr>
<td>• function in multi-disciplinary and multi-cultural teams</td>
<td>and solution;</td>
</tr>
<tr>
<td>with capacity as a leader or manager or team member;</td>
<td>• a systems approach in design &amp; operations;</td>
</tr>
<tr>
<td>• understand &amp; commit to professional &amp; ethical</td>
<td>• understand &amp; commitment to para-professional &amp;</td>
</tr>
<tr>
<td>responsibilities; and</td>
<td>ethical responsibilities; and</td>
</tr>
<tr>
<td>• a commitment to undertake life long learning.</td>
<td>• commitment to lifelong learning.</td>
</tr>
</tbody>
</table>

Australian Qualifications Framework

Much confusion was caused by changes in the credentialling systems of the technical education sector during the 1980s and 1990s, and further confusion was caused by the Australian Qualifications Framework promulgated in 1998 (AQF 1998). The transition from 1979 is illustrated in Figure 5-3. Chapter 6 argues that a systems view of the work force is dependant upon clarity and understanding of qualifications in relation to work-force roles. As Figure 5-3 indicates, such a condition applied in education in the less complex world of 1979, but confusion has been the order of the day more recently.

The 'Existing 1998' column in Figure 5-3 had a logical relationship between credentials and occupational categories. The replacement of para-professional Certificate by the Associate Diploma in the late 1980s and introduction of Advanced Certificates caused confusion for a time, but the changes provided a connection between education and work force categories and clear separation of para-professional from technician roles. The 3-year Diploma, introduced in about 1994, did not flourish in competition with 3-year Bachelor of Technology degrees.

The broad-banding approach to the Framework (AQF 1998, p. 62) created confusion through a variety of qualifications called 'Certificate', 'Diploma' and 'Advanced Diploma', without relating them to work-force roles. The new qualifications framework for the technical work force is potentially detrimental to an orderly and systematic approach to work-force organisation and management. It is important
Articulated Education

Articulated education was an idea of the late 1980s, arising from labour union moves to lower barriers to progression for people able to take educational pathways designed specifically for mature age people. The book *New Pathways in Engineering Education* (Lloyd et al. 1989) published with assistance from IEAust and APEA, defined principles for articulation for the engineering work force. Research in industry revealed support for 3-year qualifications within articulated education pathways leading to a new occupational category ‘engineering technologist’. The IEAust decision to open its membership to Engineering Technologists and para-professionals was motivated, in part, by the need to facilitate articulated education in the context of national government policies for promotion of structural efficiency and skill extension in industry. Articulation makes sense in a systems framework of definition by qualification and career progression to a higher occupation. It is a pragmatic means of strengthening leadership in the work force by widening access by mature age people to professional occupations. But the new confusing array of qualifications in the AQF is likely to inhibit systematic approaches. Articulated education envisages end-on courses for time-efficient progression through occupational levels, as illustrated in Figure 5-4.

It is not simply about 'bridging courses'. Designed correctly, it permits upward progression from one qualification to another without a need to going back to the beginning of the higher course. While the lower level course must be designed to match the work force needs of the majority who will not progress further up the occupational ladder, it should include material that prepares adequately for upward progression. These conflicting objectives require careful design. In 1991 Deakin University extended strategies for articulated education by adding the enabling element of distance education. An effective approach to articulated education requires the overturning of some traditional approaches. The essential
factors that should inform program design come from a clear understanding of the situation of participants. Some of these factors are:

- Applicants are mature age; experiential learning has extended their knowledge and skills beyond their initial credential and should attract some academic credit towards the higher qualification.
- Credit for prior learning should be for a block rather than subject for subject, and be maximised consistent with an expectation of success.
- Requirements for repetition of equivalent studies must be avoided.
- Full-time attendance is out of the question: part-time or off-campus modes give practicable opportunities.
- Motivation among participants is likely to be high and learning effective.
- Every applicant is an individual: effective programs take full account of prior learning and career needs.
- Applicants will have progressed in the horizontal dimension in their occupational category (as discussed in Chapter 6), and management studies should be an essential element of further studies.

These principles accord with principles espoused in the publication *Credit Transfer Principles: Guidelines on Recognition of Prior Learning* (AVCC, Canberra, 1993). Traditional approaches reject such considerations and demand that all students complete exactly the specified degree program for an engineering discipline. The attitude is:

- We guarantee that anyone who graduates with our degree will have completed the exact course as specified.
- If we grant any advanced standing, it will result from a detailed review subject for subject to ensure that the applicant has covered exactly the equivalent of our studies for which advanced standing is granted.
- Deficiencies must be made up by completing our studies in areas of previous study or experience.
- Every student must complete exactly the content of our standard degree course.

The more realistic approach would recognise the special nature and characteristics of the mature age applicant, and not be distorted by pedantic preoccupations with nit-picking analyses of prior studies. The attitude is:

Exact equivalence to the content of our standard degree is not required. When an applicant who has undertaken prior studies and experience seeks to complete one of our degree courses, we ask ourselves two questions:

(i) What further studies are needed to gain one of our degrees? Within the rules for maximum advanced standing, what additional studies are needed to provide a total education *equivalent* to our degree?

(ii) Having regard to prior education and experiential learning and development, and the additional studies in (i), on graduation will the applicant have a valid professional engineering (or engineering technologist) qualification? Are there any further requirements for a valid qualification?

The benchmark qualification for Engineering Technologists is the BTech degree, and other possible qualifications are omitted from Figure 5-4. Articulation from scientific and other qualifications to a professional engineering qualification also is possible. The normal professional engineering qualification for those who enter the university directly from school is the BE degree. There is merit in any program designed for articulation from a lower qualification being differentiated from the BE, to ensure that program design is specifically for articulating students. In a country such as Australia, with a work force made up of people with a great variety of educational credentials from the various States and Territories and overseas countries, articulated education must be flexible to accommodate all such variety.

When the Deakin/EEA program for the articulated BTech was designed in 1994, it was thought that it should be differentiated from the university-based approach by responding to the competency agenda espoused by the union movement. Accordingly, recognition of prior learning was to be assessed against the *Competency Standards for Engineering Associates Stage 2*. Candidates were required to submit a report to confirm that they were qualified and experienced para-professionals, eligible for credit for prior academic and experiential learning. To facilitate the claims of applicants, the specifications of study units were augmented with competency statements. But the experiment was a failure. Not one competency-based application was ever received. Three factors quickly became clear. There was no desire in the union movement for fostering articulation to degree status. The changing climate of Australian industrial relations brought less emphasis on a 'training agenda'. And most telling: potential applicants were not accustomed to writing applications of the type required, and could not connect the idea of competency to academic credit. For them, academic advancement meant 'study a subject and pass an examination'. As a result, admission criteria for the BTech were changed to a requirement to submit transcripts of prior studies and a curriculum vitae, for an assessment as to the amount of advanced standing granted. A qualified and experienced engineering para-professional could receive advanced standing up to 16 points out of 24 for the BTech.
Competency elements were retained in the MTech program. The associated studies in aspects of professionalism, and the discipline requiring students to analyse and report upon personal experiential development, were beneficial.

Articulation initiatives in the mid-1990s held promise, but by 2000 they became difficult to sustain in the face of changed government and union focus, university funding constraints and pressures on engineering schools to rationalise offerings. Such constraints were forcing most mature-age aspirants into programs designed for school leavers but inappropriate for mature experienced people.

Accreditation of Engineering Programs
In 1988 an agreement entitled Recognition of Equivalency of Engineering Education Courses/Programs Leading to an Engineering Degree was initiated at a meeting in Washington and signed by the foundation members in 1989. The initial signatories were IEAust, the Accreditation Board for Engineering and Technology (ABET, USA), the Canadian Council of Professional Engineers, the Engineering Council (UK), the Institution of Engineers of Ireland, and the Institution of Professional Engineers, New Zealand. Subsequently the Engineering Council of South Africa (1993) and the Hong Kong Institution of Engineers (1995) became signatories. Each participating body was the national organisation independent of government and responsible for accreditation of undergraduate engineering courses. The Washington Accord added new dimensions of quality assurance and protection against possible government interference in the process of determining standards in professional education for engineers.

The terms of reference of the IEAust Accreditation Board in 1991 were to conduct accreditation and monitor undergraduate engineering courses in Australia, and to formulate guidelines for professional engineering courses. The Board was to comprise at least 12 members drawn from higher education and professional practitioners within the States and Territories. Assessment was carried out through Discipline Committees and revalidation was carried out every five years. Supporting documents in the process were: Recognised School of Engineering (1990), Basic Requirements of a Professional Engineering Course (updated 1993), Management Studies in Professional Engineering Undergraduate Courses (1990), and Guidelines for the Implementation of the Policy on 4-year Professional Engineering Courses Utilising External Study Programs (1996). The Basic Requirements of an Engineering Course included accreditation criteria encompassing:

1&2. Mathematics, physics and other basic sciences, and computing, together with engineering science material, not concentrated entirely in one field. Studies were to comprise a major part of the course.
3. Engineering synthesis or design and related communication skills: said to differentiate professional engineers from engineering technologists (implying that technologists did not do design!).
4. Engineering applications material in a discipline, normally over 2 years at a depth sufficient to enable relevant published papers to be read and appreciated. A major project was expected in final year.
5&6. Principles for management of physical, human and financial resources associated with practice of engineering, and professional responsibility, social effects and ethical aspects of engineering practice.
7. Not less than 12 weeks experience relevant to engineering obtained outside the teaching establishment.

A part-time student employed in engineering normally required day release equivalent to one day per week, in a course of not less than 6 years. External studies were permitted as part of a course, but full-time attendance for the final year was essential.

The 1990 Policy on Management Studies in Professional Engineering Undergraduate Courses reflected the all-pervading nature of management in engineering practice and expected 10 per cent of the course to be in criteria 5 and 6. This was to come into full effect in 1995. Guidelines interpreted management studies as covering presentation and reporting engineering ideas, managing people and resources, economics, finance, law, marketing and business, and social and professional responsibility issues. It was recognised that courses requiring additional managerial studies would need to shorten other studies to prevent student overload.

In 1995 the IEAust revised the Policy on Professional Engineering Courses Utilising External Study Programs to waive the requirement for the final year of on-campus attendance. Engineering Schools offering external studies programs had to demonstrate that appropriate quality systems enabled students to acquire the attributes expected of a graduate engineer.

In 1998 IEAust introduced a revised process for accreditation in response to the 1996 Review of Engineering Education. At the end of 1999 an enlarged Manual for the Accreditation of Professional Engineering Programs was developed through a cooperative effort of IEAust and the Australian Coun-
cil of Engineering Deans (ACED).

The language of the Manual was adjusted to maximise international understanding, for example by use of 'program' instead of 'course'. Accreditation was placed in the hands of the six member Accreditation Board to include the National Vice-President (Formation), a senior engineering academic and at least two persons with substantial experience in organisations employing graduates in significant numbers. In addition, a formal link was established for the first time with the universities through a Joint IEAust/ACED Committee. The new feature IEAust the accreditation process was definition of the Generic Attributes required of a graduate professional engineer, discussed in Chapter 9. The essential elements in accreditation were identified as:

- **The teaching and learning environment**: Engineering education is expected to be conducted by an engineering school controlling programs, staffing and resources, and having an effective advisory mechanism involving industry participation, and adequate staff and resources.

- **The academic program**: a 4-year full-time program or equivalent, defined by philosophy and objectives, structure and content, and external benchmarking, typically including the following:
  - Mathematics, science, engineering principles, skills and tools, not less than 40 per cent.
  - Engineering design and projects, about 20%.
  - An engineering specialisation, about 20 per cent.
  - Integrated exposure to professional engineering practice, including management and ethics, about 10%.
  - More in one or more of the above or other elective studies, in the vicinity of 10 per cent.

- **Exposure to professional engineering practice**: the program is expected to engender attributes in engineering and ethics, through practical experience, staff with industry experience, guest lecturers, industry visits, an industry-based final project, and an advisory mechanism involving practising engineers and leading employers of engineering graduates, in defining program objectives, periodic evaluation and updating, evaluating capabilities of graduates, and monitoring of graduate performance in employment.

The revised system concentrates on outputs and delegates quality management to the engineering school to ensure that graduates are adequately prepared for engineering practice. In response to criticism from industry, the process places responsibilities on employers to facilitate exposure of undergraduates to practice, and to contribute to program objectives and quality systems. The IEAust will visit engineering schools at 5-year intervals to verify the process.

Membership Categories in IEAust

In the late 1990s dissatisfaction arose among para-professional leaders with the term 'engineering associate', that had been promoted for 20 years. In 1997 a generic set of membership titles and symmetrical membership grades and postnominals for Engineers, Engineering Technologists and Engineering Officers was adopted. The titles and related benchmark qualifications were agreed as: 4-year qualified - engineer, 3-year qualified - engineering technologist, 2-year qualified - engineering officer. The further decision in 1997 to complement the title Chartered Professional Engineer with Chartered status for the other categories enhanced the occupational identity of all three. The systematic membership structure in Figure 5-5 complements classification in the vertical and horizontal dimensions, as discussed in Chapter 6.

Admission to Chartered status is subject to a competency test for the occupation concerned, and continuing personal development is required for retention of that status. This arrangement clarified the standing of each category in the vertical dimension, and recognised the value of experiential development in the horizontal direction. (The expression 'continuing professional development' should be confined to professional occupations, and not misapplied to para-professional occupations. Hence the term 'continuing personal development' here.) The approach promoted value in each occupation, pride in the occupational identity flowing from qualifications and from Chartered status, and the idea of the engineering team with interdependencies that required cooperation and teamwork. This epitomises the systems view considered in detail in Chapter 6. The IEAust Bye-laws allow existing Members to retain CPEng.

The system described required acceptance of the descriptor engineering officer by engineering para-professionals at large, but it was not accepted by them. In April 1999 when the National Generic Competency Standards were published, the para-professional category was described as engineering associate, while the IEAust grade structure in Figure 5-5 remained in place even in mid-2000. This is no way to achieve an unambiguous system.
Conclusion

While the PELF much more than doubled in the two decades to 2000, growth was heavily dependent upon continuing immigration of engineers, whose numbers grew by a factor of more than three. At the same time the age profile of the engineer population shifted upwards. The IEAust assumed responsibilities for qualifications, terminology and competency definition for the professional and para-professional constituents of the engineering team. The transformation of engineering education and employment is a story of aspirations and systems, but disruption to engineering employment and ineptitude in IEAust in achieving a harmonious system, as discussed further in Chapter 15.

None of the three reviews of education discussed in this chapter questioned the excellence of education in technical studies, but there was a consistent quest for improvement in education in management. The IEAust policy on management studies for undergraduate engineers came out of pressures from engineering practice: how it was applied is analysed in Chapters 7 and 8.

It is noteworthy that the Washington Accord on mutual international recognition of accreditation was initiated at the beginning of the second phase of globalisation, acknowledging the internationalisation of engineering. The approach to accreditation was systematised during the period. As discussed in Chapter 13, the new approach reflects some of the changes in UK and USA, replacing past emphasis on inputs with concern for outcomes. However, the trends in the USA and UK are towards much less prescription of course structure and content than in the past, in contrast to the new IEAust approach. While espousing flexibility, autonomy and innovation, the new IEAust requirements are more prescriptive and quantitative than in the past. The new Australian process also draws tight boundaries around professional engineering, while the tendency in the USA and UK appears to be the opposite.

The period 1980 to 2000 began with fulfilment of the great aspiration for a degree-entry profession of engineering in Australia. Aspirations then turned to the preparation of engineers for management, as transformation of the professional paradigm began, but many engineering schools failed to respond to that imperative. By the end of the period transformation had been great, in a professional context that should have held great promise.

Note to Chapter 5

1 The decoupling of MIEAust from CPEng, as discussed in Chapter 15, and the simultaneous phasing out of the Senior Member grade, have two consequences. The first is that MIEAust (degree + 3 or so years experience without competency assessment) retains equivalence to Experienced Engineer under the Professional Engineers Awards. The second is devaluation of the traditional meaning of MIEAust because of the tacit upgrading of CPEng through competency assessment based upon a narrow conceptualisation of professional engineering practice, to a status approximately as originally envisaged for Senior Member. The question is posed in Chapter 15 as to the value of becoming an MIEAust without becoming a CPEng. The new view of CPEng, (Engineers Australia April 2001) is a status denoting current competency, as maintained by audited CPD. This previously was to be denoted by Member status in an IEAust College, and Registration on NETR, but the former now has been discontinued: everyone now is a member of the College normally denoted by original qualification, in the same grade as in IEAust. See further discussion in Chapter 15.
Chapter 6
People in the Engineering System

By Brian E Lloyd

Overview

Systems Clarity and Flexibility
A systems view of the work force requires an orderly approach to occupational terminology, definition of work-force roles, design of educational programs, and thus the design and leadership of organisations within which people work. The systems approach should not imply a ‘watertight box theory’ of occupational roles. Nevertheless, present educational paradigms require that professional degree courses be designed and delivered in a context in which course content is related to an idealised view of the work roles for which graduates are prepared. It is also necessary to apply course labels that co-ordinate with the labels applied to identified work roles.

This chapter deals mainly with two occupational work roles:
- BE or BEng (4 years): prepares for professional engineer roles.
- BTech (3 years): prepares for engineering technologist roles.

Figure 6-1 shows that the tradesperson has full Type A knowledge and skills in a particular trade, as derived from apprenticeship training and education. Technicians in mechanical and electrical occupations acquire and apply Types A and B knowledge and skills. The para-professional who does not come from a trade or technician background acquires and applies Type C knowledge and skills, as derived from a 2-year diploma, and may also have some Type B and Type A skills.

At the other end of the spectrum, the person who enters a BE course from school undertakes Type E education in high level analysis and synthesis, while also gaining the Type D knowledge and skills normally acquired by engineering technologists and Type C normal to engineering para-professionals. Figure 6-1 illustrates a role profile for an engineer envisaging some activities requiring competencies of technologists and para-professionals, and even occasional activities normal to technicians or tradespeople. But the professional engineer who begins as a tradesperson or technician and follows an articulated educational pathway through technician, para-professional and engineering technologist will gain full competency at each of Types A to E. Such an engineer would be attractive to some employers who, otherwise, might never be persuaded to engage an engineer, but it is unlikely that the role of such an engineer would require activities of Type A, B or C.

Recognising that in real life the work force requires flexibility, it would be foolish to deny that the actual work roles of engineers, engineering technologists and para-professionals overlap in the ways illustrated in Figure 6-1. It would be equally foolish to hold that an engineering technologist could perform functions at the highest level for which the engineer is educated, or that a para-professional could perform functions at the highest level for which the engineering technologist is educated. There are limits to flexibility and interchangeability.

Experience is a complicating issue. The dimension of experiential development is considered below within a systems context. In approaching the systems view, it is important to note that experiential development following qualification has to be taken into account when considering the roles of different work-force categories. In addition to the primary factor of education, overlap of roles comes about through experiential learning that builds upon initial education. For example, an experienced para-professional who has learned a great deal about a particular piece of equipment will know more about it.
that a new graduate engineer, but that does not imply any legitimacy in a claim for professional engineering status for the para-professional, even though, because of such situations, an uninformed manager might be tempted to prefer experienced para-professionals and reject engagement of graduate engineers for particular roles.

A graduate engineer has the capacity to learn quickly about any equipment, and to discern the principles and limitations of its operation and application. The para-professional might be able to design improvements in the application of the equipment, while the graduate engineer with some experience could design new generic equipment for different applications and conditions. Similarly, an experienced para-professional may carry high responsibilities requiring people and business skills, while a new graduate engineer would need a period of personal development before exercising a similar level of competency.

The remainder of this chapter discusses occupational categories as if they were watertight boxes because that is the only practicable way of addressing issues in a systems context. It is a given that definitions and educational prescriptions for each occupational category refer to the highest duties performed, the capacity for which is derived from the benchmark qualification for the category. The orderly systems approach to definition and organisation of work-force roles and design of educational programs also require an orderly approach to occupational terminology, as discussed in this chapter and in Chapter 15.

The Systems View
It is clear from the IEAust approach to accreditation, as discussed in Chapter 5, that engineering schools are the repositories and disseminators of the theoretical and practice knowledge and skills imparted to graduates for initial employment. That knowledge base is augmented, extended and refreshed by academic and industrial research, and through continuing interchange between engineering schools and industries where applications and practices are continuously extended and improved. While education for engineers underpins the engineering developments in industry, optimisation of industry effort does not rest upon professional engineers alone, nor upon an optimisation of professional engineering education in isolation from other related occupations. That is clear in systems terms.

Systems theory holds that if any element of the system is made separately to operate as effectively as possible, it does not follow that the system as a whole will be improved. Optimal performance of the whole depends more on elements working together than on how each performs separately. If we are to understand the roles of engineers in contributing to the total engineering system, we need to consider systems theory applied to the social organisation of occupations and examine the frameworks of relationships in the engineering industry and the engineering work force. Such a view depends on clarity. An engineering school catering for professionals will need to understand the total system. An effective partnership between education and industry depends upon elimination of fuzzy notions, and co-ordination of education, role definition and occupational identity for all categories that contribute to the industry system. The IEAust and APESMA are key players in the total system.

Professional Roles and Education
It is unrealistic to expect education to prepare people fully for all work functions. This chapter emphasises the importance of education that places engineering specialisms within the total system, including roles in management and leadership. Education narrowly focussed upon research and design, or a narrow specialism, is inadequate. Developments beginning in the 1980s in industry brought commitment to changing enterprise goals and people working hard to achieve them. As team leaders, professional people are expected to appreciate the abilities and aspirations of all categories of people in the work force in the new work culture.

A new element was introduced into the work-force system when IEAust defined the new professional category of Engineering Technologist and encouraged the introduction of the benchmark qualification as the BTech degree. Subsequent introduction of off-campus study provided accessible upgrading opportunities: an essential element in a total system approach. The factors that determine the limits of work roles appropriate to each occupation include an understanding of the occupational capabilities of each work force category, derived from familiarity with the education and skills of each occupation. The loop is closed by inputs to the design of educational programs for work-force occupations. These factors are essential to the systems approach, a consideration of which requires some theoretical discussion.
The Engineering System

The Engineering Industry

The engineering industry may be thought of in systems terms, as discussed in Lloyd et al. (1989). It encompasses private sector manufacturing, building and construction, utility services and consulting, together with public sector utilities, departments, local government councils, education providers and the defence forces. The engineering industry system may be conceptualised as comprising the engineering function and the engineering process, in an interdependent network of relationships illustrated in Figure 6-2. The engineering system is embedded as a sub-system within the societal system, an idea largely omitted from further discussion. Systems theory enables us to understand that the overall performance of the industry depends more upon how the components of the system operate together, than upon how each element performs separately. This is evident in a consideration of the major system elements:

- **Engineering function**: the total effort of the work force under leadership that integrates technology, business and each occupational category working co-operatively for production of outcomes.
- **Engineering process**: the range of interdependent engineering activities that transform ideas into commercial or social outcomes.

The Engineering Function

The sub-system described as the Engineering Function is about the application of technologies in enterprises, and it determines the kind of people to be employed in the engineering work force and the education and training they need. Engineering comprises a broad spectrum, from electric power, electronics, computing and control blending into mechanical engineering through mechatronics, manufacturing and process industries, to civil and structural engineering infrastructure. Social, ethical and commercial responsibilities bring all-pervading obligations concerning environmental care. The engineering team are not the only people with such obligations, and they must be equipped to listen to a range of viewpoints from others on such matters.

The engineering work force comprises all the occupations engaged in transforming engineering ideas into tangible realities. The occupations comprising 'the engineering team' are engineers, engineering technologists and para-professionals, for all of whom systems thinking provides a powerful means of integrating roles, vocational satisfaction through productive achievement, and occupational identity that flows from their qualifications.

The engineering function has to be organised to ensure that all occupational groups work together, and that there are adequate numbers of appropriately educated and trained people in each group. The systems view demands co-ordination, for each occupational group, of occupational terminology, role definition, the knowledge base needed, and the design of relevant education and training. While there may be overlapping of roles, if there is fuzziness about occupational terminology and the semantics of definitions, there will be confusion impairing overall effectiveness. Haziness lead to inappropriate expectations about what people can do: too high or too low expectations lead to stress and suboptimal performance.

All engineering work involves people within business and managerial frameworks. Engineering has to be customer driven: while the engineering function is about technology and the people who develop and apply it, it is also about the people who are affected by it. Engineering teams therefore need competencies not only in technology, but also in business and management. Managerial leadership pulls

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*Figure 6.2 Engineering Industry as a System, Comprising the Engineering Function and the Engineering Process*
everything together to meet customer needs and the commercial realities and obligations to customers and investors.

**The Engineering Process**
The Engineering Process embraces research, development, investigation, design, manufacturing, construction, installation, marketing, sales, operation and maintenance, and the all-pervading organisation and management, quality management, and environmental management. In particular enterprises not all elements of the *engineering process* necessarily are present, but each element of the *engineering function* must be present. Different sequences of process elements may be found. For example, a manufacturing enterprise has market research, product research, development and design, process design, production, sales and service. A different group of activities is undertaken, for example, in the electricity utility company that investigates demand, researches customer needs, designs and constructs facilities, operates and maintains them to provide reliable service.

The model in Figure 6-2 shows that every element of the engineering process relevant to a particular enterprise is connected to the elements of the engineering function. Feedback is the essence of process stability, and in each enterprise the elements are interconnected by complex feedback loops. Unity of purpose is crucial, whether building a dam, or making motor cars or computers. If the relationship between any of the elements becomes unbalanced, overall effectiveness is impaired. For example, a manufacturing firm must link market research to product research and development, product design must be linked tightly to production, and sales and services must provide feedback from customers to research, design and production. Systems theory emphasises a holistic view in management. Engineering management integrates the effort of the total engineering system. The unity of purpose needed for successful enterprise performance depends upon a commitment from the whole of the work-force to common shared values. Such commitment depends upon leadership, which in turn depends upon engineering knowledge and experience. It is an economic imperative that the roles and positive contributions of engineers, technologists and associates be well understood. Responsibility rests with education and the professional associations to generate such an ethos.

**Engineering Work Force**

**Human Factors**
The engineering work-force is portrayed as a system in Figure 6-3. The elements of the work force system are the groups of professional engineers, engineering technologists, para-professionals and other related occupational groups. Systems theory tells us that if any occupational group is considered separately and made to operate as effectively as possible, it does not necessarily follow that the total function will be optimised or improved. As an example of the value of the systems approach, in considering labour supply and demand at a policy level, it would be sensible to consider each group in a total context.

The diagram depicts each Occupational Group as interconnected with each other group, in ways that mean that excellence in total work-force performance relies more upon the harmonious operation of the whole than upon optimal performance of individuals or separate groups.

![Figure 6.3 The Occupational Groups in an Interconnected System](image-url)
changeability between occupational categories, optimum performance depends upon a balanced workforce.

There are people who regard roles above the first level of supervision as 'management', and beyond 'engineering', and there are some engineers who think of career development as 'moving out of engineering into management', even when they lead engineering work. In the systems approach such ideas are untenable. In Australia in the 1980s and 1990s the harmony of the work force was challenged in an environment of major change in economic and social structures. While in the 1900s some union agendas in industrial relations became excessive, it was union influences that brought beneficial contributions to an objective for upskilling the work force. In the early 1990s professional and para-professional people were making crucial leadership contributions in achieving work force harmony and productivity. Factors of observable success in many enterprises, including a growing understanding of human factors coupling education, technology and business, as considered in Lloyd (1993) and Bates et al. (1992), are summarised in the following general observations:

- Values of excellence in technology, human relations, teamwork, business and management.
- Professional and para-professional people as key players in effectiveness, leading the new industry culture.
- While such people were living demanding and busy lives, they were gaining satisfaction from their work.
- Rationalisation of the work force brought about factors such as:
  - enhanced commitment to enterprise goals, and working hard to achieve them,
  - increased vocational satisfaction, and dramatic improvements in productivity, but
  - a socially unacceptable level of unemployment, and increased contracting as contingent employees.
- Professional and para-professional people with empathy for all categories in the work force, encouraging all workers and tradespeople to be part of the team and to contribute ideas.
- A wide awareness of environmental issues, and the ethical framework for members of IEAust, reinforcing awareness of ethical and social responsibilities.

In the later period severe attacks were mounted upon working people by conservative forces seemingly motivated to cause disruption and conflict. An important public duty of professional leaders must be promotion of a greater understanding of the crucial relationships between work-force cohesion, productivity, skill enhancement and job satisfaction.

**Distribution of Work and Responsibilities**

For some social reformers the concept of equality of opportunity is translated into an idealistic but unattainable yearning for equality of outcomes. Nevertheless, governments and enterprises do have social obligations to ensure that everyone has a fair chance of finding work suitable for the level of knowledge and skills they possess. Trends in the organisation of work indicate that there is likely to be an increasing underclass having difficulty surviving without help, while knowledge workers face increasing demands for effective performance.

The high-talent knowledge workers create much of the work of the rest of the work force, and such people bear not only technical but also social responsibilities. Engineers and technologists need to be aware of these issues. The IEAust has promoted the systems view within in a social objective of assisting people to optimise their talents through a coordinated membership framework. Membership grades discussed in Chapter 5 are designed to recognise educational effort and accord status for success. In acting upon the systems view in this way, IEAust contributes to the social cohesion necessary for work-place harmony and productivity.

**Dimensions of Career Progression**

**Defining the Dimensions**

For people in any given occupational group, there are two dimensions of career progression. This is a fundamental issue in understanding education for mature age people. We need to consider how the work force is organised. In Figure 6-4, the vertical dimension refers to defined levels of knowledge and skill provided initially by *occupational entry education*. The horizontal dimension refers to career progression within an occupation, assisted by various kinds of experiential development and additional training for increased responsibilities within an occupation. The vertical dimension is concerned with levels of education, and the *additional* education essential for upward occupational transfer. Consider examples:
Horizontal Dimension: Increased Responsibility

- An Experienced Engineer may require a postgraduate course in robotics to provide knowledge and skills to design and organise a new manufacturing process. In acquiring the expertise and added responsibility, the engineer may be promoted to 'Senior Engineer', a horizontal career development.

- A Senior Engineer may take a postgraduate course in management to prepare for engineering leadership at 'Principal Engineer' level, a horizontal career move.

- An Experienced Tradesperson might need training following introduction of robots. Promotion to 'Senior Tradesperson' might follow, but this does not convert the tradesperson into a technician.

- Another tradesperson might require a post-trade course in supervision when he or she is promoted to a supervisory role as a 'senior tradesperson'. Supervision of tradespeople by a supervisory tradesperson does not represent upward occupational transfer to technician.

- An experienced para-professional might undertake a course in supervision when he or she is promoted to a supervisory role, for example, as a Principal Technical Officer. Supervision of para-professionals and others does not represent upward occupational transfer to engineering technologist.

- An Experienced Electronics para-professional might undertake industry courses in new electronic equipment, and build upon extensive prior experience to become expert in the equipment. The para-professional might feel entitled to recognition as an engineering technologist. However, adding to expertise as a para-professional without gaining enhanced capacity for analysis and syntheses and higher level understanding of technologies does not provide the competencies of an engineering technologist.

Vertical Dimension: Upward Occupational Transfer

- An Experienced Electronics Technologist wishes to become a Professional Engineer, and recognises that such transfer requires additional education. The applicant approaches EEA for assessment of prior learning and admission to an accredited professional engineering program offered in association with a university. Assessment confirms some academic credit for experiential learning, and the need to study additional mathematics, engineering applications and management. After 5 semesters of off-campus studies, and concurrent enhanced experiential development, the person graduates and is promoted to Experienced Engineer. Soon afterwards the person applies to IEAust to be a Chartered Professional Engineer. (Graduation by an experienced person into the higher occupation does not entail reverting to 'entry level' status.)

- An Experienced Electronics para-professional wishes to become an Engineering Technologist, and recognises that such transfer to professional status requires additional education. The applicant approaches EEA for assessment of prior learning and admission to a B.Tech program offered in association with a university. Assessment confirms some academic credit for experiential learning and the need to study additional mathematics, technology and management. After 2 years off-campus studies, and enhanced experiential development, the person graduates and is promoted to Senior Engineering Technologist. Soon afterwards the person applies to IEAust to be a Chartered Engineering Technologist. (Again, graduation into the higher occupation does not entail reverting to 'entry level' status.)

- An Experienced Tradesperson may undertake additional education and training in the principles and application of robots in preparation for a new and higher role. If the scope and depth of such education are adequate, occupational transfer should occur to Experienced Technician.
Salary Relativity Matrix

Not all further education contributes to upward occupational transfer; most people undertake training to underpin horizontal career progression, rather than articulated education for a higher occupation. When salary reward follows enhancement of skills, there is likely to be a greater commitment to training within occupations. The matrix in Figure 6-4 provides a generic basis for organisational design in enterprises. Figure 6-5 provides a notional model for vertical and horizontal salary relativities that take account of both dimensions.

**Table 6-1** Occupations and Qualifications in the Engineering Work Force

<table>
<thead>
<tr>
<th>Professional Engineer:</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>A person with a 4-year or equivalent higher qualification: applies advanced knowledge and skills in analysis, engineering science, advanced engineering applications and practices, management and social responsibility, to analysis and synthesis in new and existing fields in research, development, advanced design, engineering systems, manufacturing and field engineering operations and, with further formation, to specialist practice, or leadership or management roles.</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Engineering Technologist</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>A person with a 3-year or equivalent qualification: applies knowledge and skills in analysis, scientific and technological principles, management and social responsibility, to new and existing technologies in standard design, testing, inspection, engineering operations, manufacturing or field work and, with further formation, may lead or manage such work.</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Engineering Para-professional</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>A person with a two-year qualification or equivalent: works as a technical or design drafting officer, and applies practical techniques of analysis and technical principles, standards and practices, and human relations skills, to new and existing technologies in standard design, testing, inspection, engineering operations, manufacturing or field work and, with further formation, may lead or manage such work.</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Engineering Technician</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>A person with a one-year qualification or equivalent, or a higher extension of a trade formation: applies technical principles, high skills, practices, techniques and human skills to activities that include, for example, high-level manual skills, or fault diagnosis or related tasks, in a workshop, laboratory, office, field or operations function and, with further formation, may lead such activities.</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Tradesperson (or Equivalent)</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>A person with a Trade Certificate or equivalent: applies theory, practice and human relations skills to the practical activities of a trade or equivalent occupations in a workshop, laboratory, field or operation, and, with further formation, may lead such activities.</td>
<td></td>
</tr>
</tbody>
</table>

**Definitions**

This discussion leads to a need for definitions. In a system it is not possible to define any occupation in isolation from those adjacent to it, and no occupation can be defined completely without reference to the education needed for competent performance. These principles are embodied in Table 6-1. While recognising the reality of role flexibility and the possibility of some limited interchangeability between categories, the definitions refer to the benchmark qualifications for each occupational category, and to roles commensurate with such qualifications.

**Professional Occupations**

According to the Australian Standard Classification of Occupations (ASCO 1997), a professional occupation demands a qualification of three or more years full-time or equivalent, performing analytical, conceptual and creative tasks requiring high intellectual ability and an extensive body of knowledge. Accordingly *professional engineer* and *engineering technologist* are professional occupations. While engi-
neering technologists are not engineers, neither are they para-professionals. This leads to short definitions and expanded statements to illuminate professional engineering practice and engineering technology practice, as distinct professional activities similar in scope but differentiated in semantic terms as to the depth and extent of the knowledge bases required:

**Professional Engineer:** a person with a 4-year full-time or equivalent qualification accredited by IEAust, or other qualifications and experience to a standard recognised as equivalent. Such persons take responsibility for a range of professional functions in engineering. The IEAust has established criteria for admission of such persons as Professional Engineers, and for their progression to the status of Chartered Professional Engineer.

**Engineering Technologist:** a person with a 3-year full-time, or equivalent qualification in engineering technology or other related discipline, accredited by IEAust, or other Australian or overseas qualifications and experience to a standard recognised as equivalent. Such persons take responsibility for a range of professional and support functions in engineering. The IEAust has established criteria for admission of such persons as Engineering Technologists, and for their progression to the status of Chartered Engineering Technologist.

**Professional Practice in Engineering**  
*Differentiated Features of Engineers and Technologists*

- Professional Engineers require at least 4 years higher education in a substantial engineering specialism
- Engineering technologists require at least 3 years higher education in a technology field or specialism
- Professional engineering work relies upon:
  - Analysis from higher mathematics and sciences, and synthesis from a range of engineering sciences.
  - Application of advanced engineering principles and practices in and between specialisms.
- Engineering technology work relies upon:
  - Standard analysis from relevant mathematics & science, & synthesis from a field of engineering science.
  - Application of established principles and practices in a field of technology.
- Professional engineers are concerned with applied research, development and commercialisation, and advanced aspects of design, manufacture, construction, operation, maintenance.
- Engineering technologists are concerned with assisting in applied research, development and commercialisation, and standard aspects of design, manufacture, construction, operation, maintenance.

*Common Features of Engineers and Technologists.* Professional work is:

- intellectual & varied, and includes management of people, resources, facilities, processes and systems,
- directed to creation and operation of products, processes, works or services, for commercial or social needs,
- practised within a framework of ethical obligations and responsibilities to colleagues, employers and the community, and for ecological, economic and social sustainability, and
- achieves outcomes within constraints of time, cost, resources and regulations.

**Engineering Education in the Total System**

This chapter considers a variety of sub-systems and elements of the Engineering Industry System. Figure 6-6 illustrates engineering education as it relates to the work force, and aspects of society that impact directly upon engineering education providers. On the left of the diagram, R&D activities in industry, and in association with engineering schools, augment and refresh the knowledge base of education. Industry people also contribute to the academic management of courses. On the right, we may consider IEAust and APESMA as adjuncts of the work force in that they cater for the needs of members of various work-force categories, and their operations are under the control of people elected from the same work-force categories. Through these and other influences, education providers adjust their offerings to cater for work-force needs.
Engineering schools would do well to provide their school-leaver students with insights into the nature and structures of the engineering work force. Conversely, in catering for the needs of experienced mature students who return to studies for either vertical or horizontal career progression, engineering schools would do well to direct their offerings to the nature and circumstances of such students. Much two-way interaction takes place in many forms between engineering education and the work force. The outcome is an evolutionary process in which education provisions are shaped to some extent by requirements and practices in the work force, while work-force structures and practices are shaped to a large extent by the provisions of education. The Australian engineering system is embedded in an overall world system, with globalising impacts upon Australian enterprises. International professional bodies interact with counterparts in Australia in many ways, and international linkages in education have significant influences upon Australian engineering education.
Chapter 7
Engineering Education  1980-2000
By Brian E Lloyd
Introduction
The period 1980 to 2000 reveals greater change in engineering and engineering education than at any previous time. On one view, the boundaries of engineering might be said hardly to have changed during the 20th Century. Except for the rise of electronics and chemical engineering, a superficial view would see little change from 1900 when civil, electrical, mechanical and mining engineering defined the horizontal boundaries of the profession. But change has been all-pervading, especially since 1979. Table 7-2 demonstrates the proliferation of engineering specialisms as a measure of the growth in scope and diversity of engineering knowledge.

During the period there was a 50 per cent increase in the number of Australian engineering schools, a doubling of the number of undergraduate engineering students and in the number of different undergraduate courses they attend. Change included the introduction of new 3-year engineering technology programs. This chapter examines these developments. This chapter shows that the strength of education in studies in engineering fundamentals and applications continues, but attention paid to the broader context of engineering practice through studies in management in many cases is very deficient. It also shows that a variety of provisions are made for master degree programs by research or coursework, or a combination of the two. We are not concerned in this book with doctoral degree programs by research.

Australian Engineering Schools
In 2000 there were 33 universities in Australia offering professional engineering education, some with semi-autonomous operations on separate campuses. If the more significant separate campuses are counted: ADFA as a constituent of UNSW, and the Australian Maritime College, the number of Engineering Schools adds up to 35. This total omits engineering schools that integrate offerings across several campuses as at Monash, the Western Australian School of Mines as part of Curtin University, the La Trobe University College of Northern Victoria at Bendigo, and the Gold Coast campus of Griffith University.

There were 26 engineering schools in 1980, offering 113 different courses accredited by IEAust. In 2000, the 35 engineering schools offered 229 different professional engineering courses, together with another 50 separate courses for engineering technologist qualifications. Many were coy about their youthful historical roots and others made no mention of historical origins in predecessor educational bodies. Many university engineering schools have deep historical roots, as indicated in Table 7-1, but tend to ignore their origins in technical education in the 19th Century. The post-1979 engineering schools account for 29 engineering courses and 16 technology courses, but only a small proportion of student enrolments. With the exception of the University of Western Sydney, Tables 7-3 to 7-7 show that all the new schools are confined to the newer engineering specialisms or innovative approaches, while mainstream engineering education remains the task of the older engineering schools. The approach to the organisation of engineering programs differs with each engineering school because of factors of history, university structure, geographic locations, scale and other local circumstances.

Australian Capital Territory
At ANU the Faculty of Engineering and Information Technology was established in 1993 and teaches the Interdisciplinary BE in Systems Engineering, and the new BE in Software Engineering. The Interdisciplinary program integrates areas of electrical and mechanical engineering with computer systems and management. Software Engineering provides systematic analysis, design, and construction for computer systems and applications. The University of Canberra offers professional engineering courses through the School of Electronics Engineering and Applied Physics within the Faculty of Information Sciences and Engineering. The BE was introduced in 1982 in Electronics and Communications Engineering and in Computer Engineering.
New South Wales
In 1987 NSWIT was reconstituted as the University of Technology, Sydney. Engineering courses were redesigned in 1998 in response to the Enquiry into Engineering Education (Johnson 1996). The University of New England began offering engineering in the 1990s; the BE programs in Environmental Engineering and in Electronics and Communications Engineering exhibit strong foundations in science studies. Macquarie University offers BTech/MTech sequences in Information Systems, Communication Systems and Optoelectronics. The first BTechs were in 1993. The MTech is equivalent to 1.5 years FT taken PT in 2 calendar years and includes a project completed in industry. The program was designed for engineering graduates, or for an articulation route for BTech or for science graduates. The University of Western Sydney began in 1989 and offers engineering at Penrith in the School of Mechatronic, Computer and Electrical Engineering, and the School of Civic Engineering and Environment, which offers degrees in Civil and Building engineering.

Northern Territory
The Northern Territory University was established in 1989 through the amalgamation of the University College and the Darwin Institute of Technology, to offer higher and vocational education. The BE in Electrical and Electronic Engineering is the only professional engineering course offered.

Queensland
Griffith University offers the BEng at Nathan in Environmental Engineering in the Faculty of Environmental Sciences, Microelectronic Engineering in the Faculty of Engineering, and Computing and Information Technology in the Faculty of Information and Communication Technology. The Microelectronic Engineering course includes one semester in Year 3 in an industry work placement. At the Gold Coast the BEng in Civil Engineering includes three specialisms: Civil and Construction, Coastal and Environmental Engineering.

South Australia
Flinders University was opened in 1966. In 1992 a four-Faculty structure was adopted, one being Science and Engineering, and engineering education commenced in that year. The engineering courses comprise the BEng in Electrical and Electronic, and the double degree BEngBSc (Biomedical). A BEng in Computer Systems is partially implemented.

Tasmania
The University of Tasmania operates on campuses at Launceston and Hobart. The Australian Maritime College was established in northern Tasmania in 1978 and engineering courses began in about 1990. The College also provides the centre for the Australian Maritime Engineering Cooperative Research Centre, in a partnership of Monash and Curtin Universities and the University of NSW.

Victoria
In Victoria, the Deakin University engineering school was closed in 1981 when Federal Government funds were withdrawn, and reopened in 1991. Following from the developments discussed in Chapter 4, the Preston Institute of Technology site became the Bundoora campus of RMIT University in the 1990s.

Western Australia
At Edith Cowan University the School of Engineering and Mathematics in the Perth area offers BES in Computer Systems, Communication Systems and Electronic Systems. At Murdoch University, the School of Engineering offers engineering degrees in Instrumentation & Control, and in Software Engineering, at the new Rockingham campus 45 km south of Perth. At the University of Western Australia, a large engineering school on a single campus has systematised programs in a wide range of specialisms and sub-specialisms.

Table 7-1
Engineering Schools by State and First Engineering Courses

<table>
<thead>
<tr>
<th>School</th>
<th>Founded As Univ.</th>
<th>Pre 1920</th>
<th>1979</th>
<th>Post 1979</th>
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<tbody>
<tr>
<td>Australian Capital Territory</td>
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<tr>
<td>Aust Defence Force Academy</td>
<td>1986</td>
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<tr>
<td>Australian National University</td>
<td>1946</td>
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<tr>
<td>University of Canberra</td>
<td>1990</td>
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<tr>
<td>New South Wales</td>
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<tr>
<td>Macquarie University</td>
<td>1964</td>
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<tr>
<td>University of New England</td>
<td>1954</td>
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<tr>
<td>University of Newcastle</td>
<td>1965</td>
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<tr>
<td>University of New South Wales</td>
<td>1949</td>
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<tr>
<td>University of Sydney</td>
<td>1850</td>
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<tr>
<td>U of Technology Sydney</td>
<td>1987</td>
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<tr>
<td>University of Western Sydney</td>
<td>1989</td>
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<tr>
<td>University of Wollongong</td>
<td>1975</td>
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<tr>
<td>Northern Territory</td>
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<tr>
<td>Northern Territory University</td>
<td>1989</td>
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<tr>
<td>Queensland</td>
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<tr>
<td>Central Queensland University</td>
<td>1992</td>
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<tr>
<td>Griffith University</td>
<td>1974</td>
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<tr>
<td>James Cook University</td>
<td>1970</td>
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<tr>
<td>Queensland U of Technology</td>
<td>1989</td>
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<tr>
<td>University of Queensland</td>
<td>1910</td>
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<tr>
<td>U of Southern Queensland</td>
<td>1989</td>
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<tr>
<td>South Australia</td>
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<tr>
<td>Flinders University</td>
<td>1966</td>
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<tr>
<td>University of Adelaide</td>
<td>1874</td>
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<tr>
<td>University of South Australia</td>
<td>1991</td>
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<tr>
<td>Victoria</td>
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<tr>
<td>Deakin University</td>
<td>1974</td>
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<tr>
<td>La Trobe University</td>
<td>1967</td>
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<tr>
<td>Monash University</td>
<td>1961</td>
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<tr>
<td>RMIT University</td>
<td>1992</td>
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<tr>
<td>Swinburne U of Technology</td>
<td>1992</td>
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<tr>
<td>University of Ballarat</td>
<td>1993</td>
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<tr>
<td>University of Melbourne</td>
<td>1853</td>
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<td></td>
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<tr>
<td>Victoria U of Technology</td>
<td>1990</td>
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<tr>
<td>Western Australia</td>
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<tr>
<td>Curtin University of Technology</td>
<td>1987</td>
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<tr>
<td>Edith Cowan University</td>
<td>1991</td>
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<tr>
<td>Murdoch University</td>
<td>1973</td>
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<tr>
<td>University of Western Australia</td>
<td>1911</td>
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<tr>
<td>Tasmania</td>
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<tr>
<td>Australian Maritime College</td>
<td>1978</td>
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<tr>
<td>University of Tasmania</td>
<td>1890</td>
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</table>
The Student Body
A notional 'weighting' may be assigned to engineering schools, as indicated in Figure 7-1, based upon the data on gross undergraduate enrolments. The 10 post-1979 establishments account for only 7.6 percent of gross enrolments, therefore the major part of the growth in student numbers occurred in the pre-1979 engineering schools. In 1979 total Australians in engineering undergraduate courses was some 16,500, including about 1000 in diploma courses for which IEAust accreditation was about to cease. The numbers of undergraduate students in the Australian engineering schools provides an indication of the range of scale that exists. The Australian undergraduate student population therefore doubled in the two decades to 1999. The other major development was the increase in numbers undertaking a second degree along with their BE/BEng programs. A partial survey in 1999 shows 27 per cent of students undertaking double degree programs, equivalent to some 9,000 among the Australian resident students. Total undergraduate enrolment in 1999 was:1

Specialisms in Engineering
In Table 7-2 the engineering undergraduate programs offered in 2000 are grouped into related specialisms. This Section provides an analysis of the distribution of specialisms. The complex task of analysing the 229 courses in 54 specialisms across 35 engineering schools is simplified by addressing the specialism groups separately. While some are finely differentiated, the full picture of diversity emerges when broad-banding of specialisms is avoided.

Infrastructure and Environmental Group
Table 7-3 groups courses related to the infrastructure and the environment, the dominant specialisms being civil and environmental. While the core of civil engineering remains the structures, hydraulic services and transportation in the civilian infrastructure, practice has developed beyond recognition. It took educationists decades to recognise that civil engineers do not need to be expert surveyors. Early in the 20th Century surveying and geology at times were practised together, sometimes by civil engineers. In recent times surveying broadened and deepened as geomatics, integrating measurement and mapping within systems for acquisition, analysis, storage, distribution and management of spatial data.
At UNSW Geomatic Engineering is an engineering specialism covering satellite surveying, geodesy, hydrography, coastal surveying, engineering surveying, land management and development, geographic information systems, photogrammetry and remote sensing.

The new specialism of environmental engineering grew originally out of civil engineering, with emphasis on the infrastructure and ecology. There were no BE courses in environmental engineering in 1979, but by 2000 there were several sub-specialisms of that specialism embracing civil, chemical or mechanical engineering, and life sciences.

Before Environmental undergraduate degrees were introduced, environmental engineering was seen as a post-graduate activity. One of the first professional courses in environmental engineering began as a graduate diploma at Queensland University of Technology (as QIT), commencing in 1972 as a 3-year part-time course. The first Bachelor of Engineering courses to receive IEAust Preliminary Assessment were offered at the Universities of New South Wales and Western Australia in 1990. Others to follow were at Griffith and Newcastle in 1991 and the University of

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### Table 7-2

<table>
<thead>
<tr>
<th>Infrastructure &amp; Environmental</th>
<th>Elec'l &amp; Electronic Systems</th>
<th>Transportation</th>
</tr>
</thead>
<tbody>
<tr>
<td>AGR Agricultural</td>
<td>INF Information Systems</td>
<td>ARL Aeronautical</td>
</tr>
<tr>
<td>BLG Building</td>
<td>INF Info Systems &amp; Software</td>
<td>ARS Aerospace</td>
</tr>
<tr>
<td>CVL Civil</td>
<td>INF Information Technology</td>
<td>AVN Aerospace Avionics</td>
</tr>
<tr>
<td>CCN Civil &amp; Construction</td>
<td>INF Information Tech &amp;</td>
<td>NVA Naval Architecture</td>
</tr>
<tr>
<td>CVW Civil &amp; Water</td>
<td>Telecom</td>
<td></td>
</tr>
<tr>
<td>GEL Geological</td>
<td>ELC Microelectronic</td>
<td></td>
</tr>
<tr>
<td>GEM Geomatic</td>
<td>TLC Multimedia Telecom</td>
<td></td>
</tr>
<tr>
<td>OCN Ocean</td>
<td>OPT Optoelectronics</td>
<td></td>
</tr>
<tr>
<td>PRM Project &amp; Management</td>
<td>SWE Software</td>
<td></td>
</tr>
<tr>
<td>Environmental</td>
<td>SWE Software Systems</td>
<td></td>
</tr>
<tr>
<td>ENV Environmental</td>
<td>TLC Telecommunications</td>
<td></td>
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<tr>
<td>ENC Environmental (Civil)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ENM Environmental (Mech)</td>
<td>Mechatronics</td>
<td></td>
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<tr>
<td>ENS Environmental Systems</td>
<td>Robotics</td>
<td></td>
</tr>
<tr>
<td>ELC Electrical &amp; Computer</td>
<td>Mechatronics</td>
<td></td>
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<tr>
<td>ELC Electrical &amp; Electronic</td>
<td>MFG Manufacturing</td>
<td></td>
</tr>
<tr>
<td>ELL Electrical &amp; Mechatronic</td>
<td>MCL Mechanical</td>
<td></td>
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<tr>
<td>ELL Electrical</td>
<td>MCL Mechanical &amp; Space</td>
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<tr>
<td>ELP Electrical Power</td>
<td>MCL Mechanical &amp; Space</td>
<td></td>
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<tr>
<td>ELC Electronic &amp; Comm/Comput</td>
<td>MCL Mechanical &amp; Space</td>
<td></td>
</tr>
<tr>
<td>ELC Electronic/Elec Systems</td>
<td>MCL Mechanical &amp; Space</td>
<td></td>
</tr>
<tr>
<td>ELC Electronics &amp; Microelectronic</td>
<td>BML Biomedical</td>
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</tr>
<tr>
<td>Note: Italic denotes courses related to main exemplars.</td>
<td>MED Medical</td>
<td></td>
</tr>
</tbody>
</table>

At UNSW Geomatic Engineering is an engineering specialism covering satellite surveying, geodesy, hydrography, coastal surveying, engineering surveying, land management and development, geographic information systems, photogrammetry and remote sensing.

### Table 7-3

<table>
<thead>
<tr>
<th>Acronyms, see Table 7-2</th>
<th>AGR CGN ELC ENS ENV PRM</th>
<th>Aus Capital Territory</th>
<th>New South Wales</th>
<th>Queensland</th>
<th>South Australia</th>
<th>Victoria</th>
<th>Western Australia</th>
<th>Tasmania</th>
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<tbody>
<tr>
<td>Aus Defence Force Academy</td>
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<td>University of Sydney</td>
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<td>U of Technology Sydney</td>
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<td>U of Western Sydney</td>
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<td>University of Wollongong</td>
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<td>Griffith University</td>
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<td>RMIT University</td>
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<td>Swinburne U of Technology</td>
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<td>Victoria U of Technology</td>
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<td>Curtin U of Technology U of Western Australia</td>
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By 1996 the IEAust listed 13 courses, and Table 7-3 lists 19 courses for 2000. The proliferation of courses is evidence of a recognition of the importance of the subject, but it also may indicate a bandwagon effect to attract students to new marketable areas.

Environmental engineering has become diversified into sub-specialisms. At Newcastle there are optional strands in biology, chemical engineering, chemistry and geotechnical engineering. At the University of Queensland a wide range of electives is presented. At the University of Western Australia there are three streams associated with civil and another in Resources Engineering. At the University of Melbourne, one specialism in environmental engineering is associated with civil and another Mechanical and Manufacturing.

Electrical & Electronics
In 2000 the trend in electrical engineering towards electronics and away from electrical power was evident in all but a few courses. Electrical engineering has evolved into specialisms within specialisms.

Tables 7-4 groups courses in electronic engineering and the related areas of computers, information technology and software engineering, and Table 7-5 sets out courses called electrical engineering. During the 1990s, university teaching resources concentrated more and more on the glamour of the Information Age.

A question for the 21st Century therefore is: where will electrical power engineers come from? The work force in the electricity industry includes some 5,000 professional engineers, predominantly in electrical power. Such a professional group requires continuous graduate recruitment, but planning for future needs in electrical power has been impaired by industry fragmentation, restructuring, downsizing and privatisation. The future therefore could hold difficulties for the electricity and other industries in requiring engineers with education in power engineering. These are the impressions from an initial review of courses on electrical engineering, but what are the facts?

Electronics, Computer and Related Group
Table 7-4 shows the diversity of courses based upon electronics and computing, the areas in which the envelope of engineering was redefined in the 1990s. The diversity of approaches to electronics and related studies is represented in courses with variants in communications, electronics and computing or computronics, electronic systems, instrumentation and control, microelectronics, optoelectronics and telecommunications. There are courses in computer engineering dealing in varying degrees with digital electronics, signal processing, and the hardware and software of computers and computer networks. Others are devoted to information technology and software engineering, some with little attention to hardware. The IEAust list of 1992 included no courses in software or telecommunications engineering, and only two in information technology.

Electrical Engineering
The analysis of the courses called electrical engineering in Table 7-5 indicates the approach to teaching electrical power engineering. The scope of various aspects of electrical power is indicated in terms of core
and elective studies in the major elements of the specialism, and quantified as to the proportion of such studies in Engineering Applications. These two factors and a review of each course enable broad conclusions to be drawn in Table 7-5 as to emphasis on power engineering. For example, a wide scope of studies in power engineering occupying more than half Engineering Applications is classified as Strong Emphasis. Narrow scope in less than half Engineering Applications studies is Light Emphasis.

Six electrical engineering courses in Australia showed strong emphasis on electrical power engineering. Several others provided some grounding in the specialism, as a basis for experiential learning and postgraduate studies. Thus the situation postulated above is not as gloomy as first impressions indicate. However, only a small proportion of graduates in electrical engineering will be thoroughly prepared for competent practice in electrical power engineering, presenting risks industry and ethical challenges for graduates. 

### Mechanical and Related Specialisms

As indicated in Table 7-6, electronics and computing have invaded mechanical engineering in the form of mechatronics, biomedical engineering, avionics, automated machine systems and robotics. Emphasis varies: at UNSW mechanical studies are complemented by microelectronics and control, the University of Sydney includes more electrical and electronic engineering, while at UWS electrical and electronic engineering, control and robotics, are supported by mechanical studies. Mainstream mechanical engineering accounts for 22 courses, while there are 6 in manufacturing, one in industrial engineering, and one in Automated Machine Systems at Ballarat. There are three courses in biomedical and related specialisms, although some other courses include such studies as options. Transportation specialisms are represented by 5 courses in aeronautical, aerospace and avionics engineering, and two in naval architecture.

### Process, Resources and Related Specialisms

The 38 courses set out in Table 7-6 represent a diversity of specialisms, the dominant group being concerned with industrial processes. The UNSW offers process metallurgy, and mineral processing is offered at the Universities of Queensland and South Australia. At UNSW, IEAust has accredited a 4-year BSc in Industrial Chemistry, and Murdoch University introduced a similar course in 2000 for the BE in Engineering Chemistry. The only course in metallurgical engineering is at UNSW.

<table>
<thead>
<tr>
<th>Table 7-5</th>
<th>Electrical Engineering Courses by Power Content</th>
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</thead>
<tbody>
<tr>
<td>ACT</td>
<td>Aus Defence Force Acad</td>
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<tr>
<td>New South Wales</td>
<td>University of Newcastle</td>
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<td>University of NSW</td>
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<td>University of Sydney</td>
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<td>U of Technology Sydney</td>
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<td>U of Western Sydney</td>
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<td>University of Wollongong</td>
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<td>Northern Territory U Queensland</td>
<td>Central Queensland U</td>
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<td>James Cook University</td>
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<td>Queensland U of Tech</td>
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<td>U of Southern Queensland</td>
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<td>Flinders University</td>
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<td>University of Adelaide</td>
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<td>University of SA Adelaide</td>
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<td></td>
<td>University of SA Whyalla</td>
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<td>Victoria</td>
<td>Monash University</td>
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<td>RMIT University</td>
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<td>Swinburne U of Technology</td>
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<td>University of Melbourne</td>
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<td></td>
<td>Victoria U of Technology</td>
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<tr>
<td>Western Australia</td>
<td>Curtin U of Technology</td>
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<td></td>
<td>U of Western Australia</td>
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<tr>
<td>Tasmania</td>
<td>University of Tasmania</td>
</tr>
</tbody>
</table>

Acronyms, see Table 7-2.

2 = double major.

<table>
<thead>
<tr>
<th>Emphasis</th>
<th>CMP</th>
<th>ELC</th>
<th>MNL</th>
<th>ELP</th>
<th>Control</th>
<th>Elec Utilisation</th>
<th>Energy Conv</th>
<th>Elec Drives</th>
<th>Elec Systems</th>
<th>Mechanical</th>
<th>Pwr Syst Prot’n</th>
<th>Pwr Electronics</th>
<th>% Eng Applic’ns</th>
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<tbody>
<tr>
<td>Strong</td>
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</table>

% Eng Applic’ns

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33
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48
48
55
Mineral Engineering is offered by the Western Australian School of Mines (Curtin), while the University of South Australia combines minerals and materials engineering. There are six courses in Mining Engineering, two in NSW, and the Western Australian School of Mines complements mining with a BEng in mining geology. The only course in Petroleum Engineering is at UNSW. There are five in Materials Engineering, and RMIT offers Polymer Engineering. The University of Western Australia provides the range of sub-specialisms within Resources shown in Figure 7-1.

Interdisciplinary Courses
The two interdisciplinary programs in Table 7-6 have different objectives. The BE at ANU integrates areas of computing, telecommunications, manufacturing, energy, materials and management. The program is the same for all students in the first three years, and electives and project work in Year 4 provide some choice. The interdisciplinary BE at Monash Gippsland provides a strategy for a small student body. It is offered on and off-campus with much common studies and choices in civil, electrical, mechanical or information technology.

Structure of Engineering Programs
The new approach by IEAust to accreditation described in Chapter 5 reflects globalisation of engineering. While the approach espouses flexibility, autonomy and innovation, the requirements are more quantitative than in previous approaches. Prescriptions for distribution of studies by category provide a basis for comparative analysis of Australian professional engineering programs. An analysis as to how the engineering schools respond to the prescriptions, based upon averaging for each engineering school the percentage distribution of their program contents by category, gives general indications of the approaches taken by the engineering schools. Findings are:
- Categories 1 & 2. Mathematics, science, computing, engineering science: not less than 40%: All but a few comply.
- Category 3. Design and projects, about 20%: a few exceed, many fall far short.
- Category 4. Engineering applications, about 20%: most exceed it, and a few fall short.
- Category 5. Management and ethics about 10%: compliance variable between engineering schools and their programs, as discussed below.
- Category 6. Other elective studies, in the vicinity of 10%: only a few have studies not in Categories 1 to 5.

Tables 7-7 and 7-8 provide analyses for Victoria and NSW for Civil and Electrical Engineering, and disclose some wide divergences from the new IEAust accreditation prescriptions.

Engineering Management
Until 1979 engineering educators generally ignored the management dimension in the employment destinations of graduates. The teaching of management in engineering undergraduate courses was zero in most courses and minuscule in the others. A few schools had begun to add some humanities studies that contributed nothing to management awareness or skills. The deficiency became recognised within IEAust, and in 1991 the Policy on Management Education in Professional Engineering Undergraduate Courses was published.

An analysis of engineering courses shows that the Policy has been applied with enthusiasm by about one-third of the engineering schools, and fairly well in another third, other responses appear to be so ineffectual as to indicate that the educators concerned simply do not get it concerning the nature of modern professional engineering employment.

Table 7-7 shows in civil engineering at Swinburne University of Technology, and in electrical engineering at Monash and RMIT, management studies fell well short of the requirement. Table 7-8 shows that in NSW only the University of Technology Sydney complied in civil and electrical engineering, while the other universities listed fall short, especially in electrical engineering. That the Policy was ignored calls into question the efficacy of the accreditation function.

Ideally management is integrated into other studies. However, practicalities dictate for most that it be taught in separate subjects, as it is in most courses, because of the difficulties in finding engineering lecturers able to, or interested in, teaching management.
Engineering Technology Programs

In 1999 engineering technology programs were offered in 19 engineering schools, as summarised in Table 7-9. All programs are 3 years full time or equivalent, and all were introduced in the mid-1990s. At ADFA, Year 1 of the full-time BTech in Aeronautical Engineering is the same as for the BE, and a choice of options in the third year allows some specialisation. Under normal circumstances a BTech graduate may articulate to the BE in Aeronautical Engineering with 18 months additional study. Before completing their academic studies students must complete 20 days of approved practical experience in one block with one employer.

In NSW, with the exception of Macquarie University described above, technology programs are designed for articulation from TAFE, but in some cases direct admission from school also is possible. At UWS students complete three semesters in electrical or mechanical technology at a TAFE college, together with engineering mathematics, and transfer to UWS for Semesters 4, 5 and 6. At the University of Wollongong, BTechs were offered in Civil, Materials and Mechanical Technology, but small numbers of students lead to withdrawal of the programs.

At the NT University in 1999 Bachelor of Technology (TBTech) (sic) courses were introduced in civil, mechanical, electrical and electronics technology, with admission from a TAFE qualification. Central Queensland University requires on-campus attendance for Years 1 and 2, but allows Year 3 to be taken on-campus or by distance education. However, Industrial Instrumentation is offered entirely off-campus. At the University of Southern Queensland, BTech programs are offered on and off-campus. The Australian Maritime College provides a 3-year Bachelor of Applied Science in Maritime Technology. The BTech programs at the University of Tasmania are articulated from TAFE.

In Victoria, at Deakin BTech programs are based upon selections of units from the parallel BE programs, and an additional program in Coastal Resource Management also is provided, all on and off-campus. The BTech programs are differentiated from the BE as to admission requirements and in the mathematics and physics studies taken. At La Trobe University a similar approach is taken for the full-time BTech programs, but with some differentiation in Year 3 from the BE. At Monash University, Caulfield campus, the BTech programs are articulated from TAFE. At VUT, the full-time BSc programs indicated in Table 7-9 are suitable for engineering technology employment.

In WA, at Edith Cowan University the 3-year BTech (Electronic Systems) at Bunbury covers elec-

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The compartmentalisation of 'non-technical' studies might be a reflection of mindsets in which management is a mystery. Evidently there remains a major obstacle to the integration of management thinking into the teaching of engineering, and in thereby conveying appropriate attitudes to students about the realities of engineering practice.

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### Table 7-9

<table>
<thead>
<tr>
<th>Engineering Technology Courses</th>
</tr>
</thead>
<tbody>
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<td><strong>Acronyms, see Table 7-2 and as noted.</strong></td>
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</tr>
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<td>○ Entered from school or with advanced standing</td>
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</tr>
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</tr>
<tr>
<td>New South Wales</td>
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<td>U of Southern Q’land</td>
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<tr>
<td>South Australia</td>
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<tr>
<td><strong>Victoria</strong></td>
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<td>Deakin University</td>
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<tr>
<td>La Trobe University</td>
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<tr>
<td>Monash University</td>
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<tr>
<td>Victoria U of Tech (BSc)</td>
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<tr>
<td>○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○</td>
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<tr>
<td><strong>Western Australia</strong></td>
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<td>Edith Cowan University</td>
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<tr>
<td><strong>Tasmania</strong></td>
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<tr>
<td>Aus Maritime College</td>
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<td>University of Tasmania</td>
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</table>
tronic, communication and computer systems in telecommunications, instrumentation and other applied electronic technology areas. At Murdoch University, two BTech courses are offered, in Computing and Instrumentation & Control, for direct entry for school leavers or articulation from an appropriate course completed at South Metropolitan College of TAFE.

University-Based Master Degrees

A survey of Australian engineering schools in Table 7-10 summarises practices in relation to on-campus research and coursework master degree programs in three categories:

- **Research:** For a supervised research project on campus, or sometimes in an arrangement with an employer. Generally no coursework is required. Admission normally requires an honours degree in engineering for young candidates, or demonstrated professional achievement for mature engineer candidates. The award may be ME or MEngSc, with ME in the majority of courses.

- **Professional Practice:** For mature experienced engineers who prepare an unsupervised thesis based upon an investigation, design or other advanced professional achievement. This is a traditional award from older universities, and does not seem to apply in the newer universities. The award normally is an ME.

- **Continuing Professional Development:** The candidate completes a coursework program, in many cases with a project report. Generally programs are taken by mature people with a degree in engineering (or equivalent professional recognition) and demonstrated professional achievement. The award may be ME or MEngSc, with MEngSc (or variants) in a small majority over ME.

There is no standardisation: ME and MEngSc are used for research and coursework programs, and many universities apply the same award for both categories. Admission generally is expressed as 'an honours degree in engineering, or an engineering degree with good experience indicating ability to complete a postgraduate program'. A few require preliminary coursework. A logical rationalisation of master degrees in engineering is required. The award of MEngSc does not sit well with coursework programs because their essence is not 'scientific.' Academic research degrees might be better presenting a 'science' image as in MEngSc. There would be an advantage in differentiating such degrees from coursework and professional degrees as:

- Research degree (university supervised research): MEngSc
- Professional degree (industry-based R&D or professional practice): ME
- Coursework degree (studies in advanced professional practice): ME

Such an approach would sit well with long established practice in many universities. The MTech (8 point) program at Deakin and the MET (12 point) at USQ do not fit this mould, but serve different purposes. As in science, research doctorates in engineering are more popular than master degrees by research. In 1998 the number of PhD awards exceed 430, twice the number of research master degrees. The total number graduating from research and coursework master degrees in engineering was approximately 1100.

Conclusion

This chapter summarises the state of engineering education in Australia at the end of the 20th century. The period 1980 to 2000 was one of great change in engineering education, with proliferation of engineering specialisms responding to the growth in diversity of engineering knowledge and its application. The period saw a 50 per cent increase in the number of engineering schools, a doubling of the number of undergraduate engineering students and the number of different undergraduate courses they attend, and introduction of new engineering technology programs.

It reveals a situation of great variety of the scale and offerings in a large number of engineering schools. There are 12 schools where undergraduate enrolments exceed 1500, and 13 schools where enrolments are fewer than 500. While the strength of education in studies in engineering fundamentals and applications is undoubted, attention paid to the broader context of engineering practice through studies in management in many cases is very deficient. Analysis discloses a variety of approaches and many significant engineering schools ignoring the IEAust policy requiring 10 per cent of program devoted to such studies. The new IEAust accreditation policy seems likely to absolve most of the laggards in management studies from changing anything, as just about any non-technical course content will count towards the 'about 10 per cent' requirement. A cynical conclusion could be that the new criterion was adopted to fit the current situation, rather than to define a principle against which engineering programs should be judged.
### Table 7-10
Master Degrees in Engineering

<table>
<thead>
<tr>
<th>University</th>
<th>Degree</th>
<th>Admission</th>
<th>Content</th>
<th>Degree</th>
<th>Admission</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADFA (UNSW College)</td>
<td>ME</td>
<td>H2 or higher</td>
<td>RT</td>
<td>MEngSc</td>
<td>4-yr degree</td>
<td>2 Sem FT or 4 yr PT</td>
</tr>
<tr>
<td>Australian National U</td>
<td>ME</td>
<td>Good degree</td>
<td>RT</td>
<td>MMaintMg</td>
<td>Degree</td>
<td>2 Sem + Project</td>
</tr>
<tr>
<td>Central Queensland U</td>
<td>ME</td>
<td>Hons or equiv</td>
<td>RT</td>
<td>MEngSc</td>
<td>Hons or equiv</td>
<td>2 Sem FT or 4 yr PT</td>
</tr>
<tr>
<td>Curtin U of Technology</td>
<td>ME</td>
<td>Hons or equiv</td>
<td>RT</td>
<td>ME</td>
<td>Experience</td>
<td>12 pt C + T</td>
</tr>
<tr>
<td>Deakin University</td>
<td>ME</td>
<td>Hons or equiv</td>
<td>RT</td>
<td>MEngSc</td>
<td>Hons or equiv</td>
<td>8 points C</td>
</tr>
<tr>
<td>Edith Cowan University</td>
<td>MEngSc</td>
<td>Hons or equiv</td>
<td>RT</td>
<td>MEngSc</td>
<td>Hons or equiv</td>
<td>2 Sem FT or 4 PT</td>
</tr>
<tr>
<td>Flinders University</td>
<td>ME</td>
<td>Hons or equiv</td>
<td>RT</td>
<td>MSoftEng</td>
<td>Degree</td>
<td>16 pt C + T 8 pt</td>
</tr>
<tr>
<td>Griffith University</td>
<td>ME</td>
<td>Hons or equiv</td>
<td>Prac</td>
<td>MEngSc</td>
<td>Hons or equiv</td>
<td>1.5 years FT or 3 yr PT</td>
</tr>
<tr>
<td>James Cook University</td>
<td>MEngSc</td>
<td>Hons or equiv</td>
<td>PracT</td>
<td>MEngSc</td>
<td>Hons or equiv</td>
<td>1 yr FT, 1/3 C + T</td>
</tr>
<tr>
<td>La Trobe University</td>
<td>ME</td>
<td>Hons or equiv</td>
<td>PracT</td>
<td>MEngSc</td>
<td>Hons or equiv</td>
<td>2 yrs PT</td>
</tr>
<tr>
<td>Macquarie University</td>
<td>ME</td>
<td>Hons or equiv</td>
<td>PracT</td>
<td>MEngSc</td>
<td>Hons or equiv</td>
<td>1 Yr FT, 2/3 C + T</td>
</tr>
<tr>
<td>Monash University</td>
<td>ME</td>
<td>Hons or equiv</td>
<td>PracT</td>
<td>MEngSc</td>
<td>Hons or equiv</td>
<td>1 yr FT, 3/4 C + T</td>
</tr>
<tr>
<td>Murdoch University</td>
<td>ME</td>
<td>Experience</td>
<td>RT</td>
<td>MEngSc</td>
<td>Hons or equiv</td>
<td>1.5 years FT or 3 yr PT</td>
</tr>
<tr>
<td>Northern Territory U</td>
<td>ME</td>
<td>BE degree</td>
<td>RT</td>
<td>MEngSc</td>
<td>Hons or equiv</td>
<td>2 yrs PT</td>
</tr>
<tr>
<td>Q'land U of Technology</td>
<td>ME</td>
<td>Degree</td>
<td>RT</td>
<td>MEngSc</td>
<td>Hons or equiv</td>
<td>3 yrs PT</td>
</tr>
<tr>
<td>RMIT University</td>
<td>MEngSc</td>
<td>Hons or equiv</td>
<td>RT</td>
<td>MEngSc</td>
<td>Hons or equiv</td>
<td>1.5 yrs FT or 3 yrs PT</td>
</tr>
<tr>
<td>Swinburne U of Tech</td>
<td>MEngSc</td>
<td>Degree</td>
<td>C + RT</td>
<td>MEngSt</td>
<td>Degree</td>
<td>C + 1 yr</td>
</tr>
<tr>
<td>University of Adelaide</td>
<td>ME</td>
<td>Degree</td>
<td>PracT</td>
<td>U of Adelaide</td>
<td>Degree</td>
<td>1.25 yr FT or equiv</td>
</tr>
<tr>
<td>University of Ballarat</td>
<td>MEngSc</td>
<td>Degree</td>
<td>PracT</td>
<td>U of Melbourne</td>
<td>Degree</td>
<td>12 point</td>
</tr>
<tr>
<td>University of Canberra</td>
<td>ME</td>
<td>Hons or equiv</td>
<td>RT</td>
<td>ME</td>
<td>Degree</td>
<td>C+T</td>
</tr>
<tr>
<td>University of Melbourne</td>
<td>ME</td>
<td>Degree</td>
<td>PracT</td>
<td>ME</td>
<td>Degree</td>
<td>C + project T</td>
</tr>
<tr>
<td>U of Newcastle</td>
<td>ME</td>
<td>Degree</td>
<td>PracT</td>
<td>ME</td>
<td>Degree</td>
<td>1 yr equiv C, or + T</td>
</tr>
<tr>
<td>University of NSW</td>
<td>ME</td>
<td>Degree</td>
<td>PracT</td>
<td>U of Queensland</td>
<td>Degree</td>
<td>1 yr equiv C + T</td>
</tr>
<tr>
<td>U of Queensland</td>
<td>ME</td>
<td>Degree</td>
<td>PracT</td>
<td>U of South Australia</td>
<td>Degree</td>
<td>1 yr equiv C + T</td>
</tr>
<tr>
<td>U South of Australia</td>
<td>ME</td>
<td>Hons or equiv</td>
<td>RT</td>
<td>U Southern O'land</td>
<td>Degree</td>
<td>2 Sem FT or equiv</td>
</tr>
<tr>
<td>University of Sydney</td>
<td>ME</td>
<td>Degree</td>
<td>PracT</td>
<td>University of Sydney</td>
<td>Degree</td>
<td>2 Sem FT or equiv</td>
</tr>
<tr>
<td>University of Tasmania</td>
<td>ME</td>
<td>Degree</td>
<td>PracT</td>
<td>University of Tasmania</td>
<td>Degree</td>
<td>1 yr FT or equiv</td>
</tr>
<tr>
<td>U Technology Sydney</td>
<td>ME</td>
<td>Degree</td>
<td>PracT</td>
<td>U Technology Sydney</td>
<td>Degree</td>
<td>1 yr FT or equiv</td>
</tr>
<tr>
<td>U Western Australia</td>
<td>MEngSc</td>
<td>Degree</td>
<td>PracT</td>
<td>U Western Australia</td>
<td>Degree</td>
<td>1 yr FT or equiv</td>
</tr>
<tr>
<td>U of Western Sydney</td>
<td>MEHons</td>
<td>Degree</td>
<td>PracT</td>
<td>U of Western Sydney</td>
<td>Degree</td>
<td>1 yr FT or equiv</td>
</tr>
<tr>
<td>U of Wollongong</td>
<td>MEHons</td>
<td>Degree</td>
<td>PracT</td>
<td>U of Wollongong</td>
<td>Degree</td>
<td>1 yr FT or equiv</td>
</tr>
<tr>
<td>Victoria U of Tech</td>
<td>ME</td>
<td>Hons or equiv</td>
<td>C+RT</td>
<td>Victoria U of Tech</td>
<td>Degree</td>
<td>1.5 yrs FT or equiv</td>
</tr>
</tbody>
</table>

RT = research thesis
P prac = assessed prof practice
C+RT = Coursework and research thesis
PracT = Prf practice thesis
T = Thesis or equivalent report
Ni = no information

Programs for master degrees overwhelmingly concentrate on engineering technology: the engineering schools pass responsibility for the teaching of postgraduate engineering management to the business and management schools.
Notes to Chapter 7

1 Data on persons enrolled (not EFTS) mainly is from Ashenden and Milligan (1999). Additional data was obtained from a survey of engineering schools, returns representing about half the total student body correlated well with Ashenden and Milligan. This additional data provided the basis for estimating the student body in BTech programs, and the number of BE/BEng students in double degree programs.

2 As computed in Rice and Lloyd (1991), p. 89. The work force of 5,000 is unlikely to have grown since 1991.

3 Chowdhury, B H (2000) ‘Power Education at the Crossroads’, IEE Spectrum, October 2000, reports on the serious situation of education for electrical power engineering in the United States, a story only too familiar in Australia:

   The electric power industry in the United States is facing a disquieting shortage of trained engineering personnel. For decades, things have gone downhill. The salaries paid to power engineers have been lower than those of virtually all other electrical engineers. Student enrolments have steadily declined. University programs have atrophied.

   To top things off, as the electric power industry has been radically reorganised in the last 10 years to allow for greater competition, utilities have economised by cutting staff, even as the technical requirements of running their operations have become spectacularly more demanding. While power engineering has continued to attract engineering school students overseas, where positions in industry enjoy prestige and competitive salaries, the effect has been to aggravate the situation in the United States.

   "After spending the last decade on downsizing, rightsizings, re-engineering, business process improvements, and trying to meet the next quarter's earnings goal, there is an immediate critical shortage of power engineers required to perform basic transmission and distribution planning and engineering," said Carl Mycoff, head of Mycoff & Associates, a leading placement firm that specialises in putting power engineers to work. Mycoff, based in Denver, Colo., expects the shortage of power engineers to worsen noticeably over the next five years. . . .

   Although power engineering has not retained the status it once enjoyed among students and the faculty who train them, it remains the lynchpin of a huge industry on which virtually all other industries rely.

   The leading power engineering companies — General Electric, Siemens, Alsthom, and ABB - are among the world's biggest and most prestigious corporations. To be sure, the power-related business segment makes up only a fraction of what these highly diversified companies do. But that segment still represents a large and rapidly growing market - not a week goes by, indeed, without the announcement of some major international power transaction involving one of those companies.

   Platts Utility Data Institute, a division of McGraw-Hill in New York City, predicts that over the next 10 years more than 750 GW of new generating capacity will be installed worldwide, requiring an investment of US $US500 billion. That scenario represents a huge opportunity, not only for plant manufacturers but also for providers of energy services. . . .

4 Note that, in the postnominal for the Master of Engineering Science, the abbreviation for Science is 'Sc', as in BSc. When the colloquial pronunciation is 'em eng sye', the tendency to write 'MEngSci' is rather gauche. Use of MEng instead of ME for the master of Engineering in some universities is a legacy of their previous status as Colleges of Advanced Education; the more usual postnominal for Master of Engineering is ME. The degree of 'Master' denotes mastery of a field of study. An apostrophe, as in 'Master's degree', would denote possession of a degree by a 'master'. When the plural is used, as in 'Masters Degree', what is meant? It is not the possessive, so why the 's'?
Chapter 8
Management Studies in Engineering Courses

By Stuart Palmer

What is Engineering Management?
To be able to investigate management studies in engineering courses it is essential to define what the term ‘engineering management’ means. The following are some examples.

Few people would dispute the proposition that shortly after beginning their careers, many professional engineers move from spending the bulk of their time solving technical problems to doing other things . . . . They are managerial activities. Management can be defined in many different ways, most of which include reference to planning, organising, controlling, leading, directing, allocating resources, communicating and coordinating. (Samson 1995).

Most graduate engineers in business in Australia will devote only a small part of their working lives to traditional engineering activities,...Instead, they will spend most of their working lives in activities which might be termed management activities, that is activities related to planning, organising, controlling, communicating, decision-making and so on. (Kinsky 1994).

. . . engineering managers are under pressure to achieve marketable results focusing on quality, cost, and speed. This requires effective planning, organization, and integration of complicated multidisciplinary activities across functional lines and a great deal of people skills. (Thamhain 1992).

Between the inception and completion of any engineering project there is a vast expanse of management and administrative tasks. Each of these, however, will be seen as connected with one of the six basic management functions (Antill and Farmer 1991): planning, organising, staffing, directing, controlling and coordinating.

These definitions incorporate some form of the commonly accepted functions of general management, that is, ‘planning, organising, leading and controlling’. So, obviously, an engineering manager is not too far removed from any other kind of manager, but not quite the same either. Perhaps this essential difference is best described by Babcock (1996):

The engineering manager is distinguished from other managers because he [or she] possesses both the ability to apply engineering principles and a skill in organizing and directing people and projects. He is uniquely qualified for two types of jobs: the management of technical functions (such as design or production) in almost any enterprise, or the management of broader functions (such as marketing or top management) in a high-technology enterprise.

Engineering management is the application of general management skills to the task of managing engineering activities. This definition also highlights the general nature of the management task - it is quite possible for an engineering manager to focus on the management of technological activities, or to become involved in the management of other activities that support the engineering function, or even to move completely into general management. From a systems perspective, engineering management is the factor that integrates all the elements of the engineering process.

It is important to understand the functions of management (planning, organising, leading, controlling, etc), but they do not tell us what areas of knowledge an engineering manager requires to be able to apply these functions to the management of technology. Obviously, it is impossible to be prescriptive here, as every manager, engineering or otherwise, faces a unique set of circumstances. For the practising professional engineer, their experience of management is likely to change as their career develops. A typical progression might include several of the following phases:

• as a graduate: focus on self-management in the efficient completion of tasks;
• as an experienced engineer: responsibility for an engineering team;
• as a senior engineer: responsibility for an engineering project;
• as a functional manager: responsibility for departmental operations, budget and coordination;
• as a general manager: coordination and operation of all business functions;
• as a sole practitioner: total technical and business management responsibility; and
• as an entrepreneur: establishment of a new business enterprise.
Just as it is impossible for a course to provide students with all of the technical knowledge they will ever need, it is also clearly impossible to equip an undergraduate with all of the management skills they will need during their career. However, in the past there has existed guidance for those developing and delivering undergraduate engineering courses as to what areas of knowledge and skill should be included in management studies. As noted later, this guidance has recently been significantly altered and weakened.

The IEAust Accreditation Policies and Procedures in 1991 relating to Professional Engineering Undergraduate Courses (IEAust 1991b) provide a ‘Model Study Structure’ for undergraduate management studies (IEAust 1990b and 1991c). The model offers a suggested course content but is not intended to be prescriptive, although it does provide one view of the basic management knowledge required by engineering graduates. The actual model study structure is very detailed, but an appreciation of the content can be gained from the titles of the 17 suggested modules of study:

- Introduction to engineering management
- Communication for engineers
- Economics
- Accounting for engineers
- Law for engineers
- The engineer and society
- Organisational behaviour
- Engineering economics
- Managing people
- Marketing for engineers
- Engineering finance
- Management science
- Human resource management
- Operations and quality management
- Business strategies for engineers
- Engineering and project management
- Engineering innovation

The suggested model study structure, if fully implemented, would provide a good coverage of engineering management issues at the undergraduate level. It also provides an insight into the diverse range of skills needed by the engineering manager. It is self-apparent that if fully implemented, the suggested study structure would be a significant component of an undergraduate course. It would not fit into a one or two subject elective option, but requires a fully-fledged management sub-major stream across the course. Such a weighting appropriately reflects the importance of management to the long-term career of the practising professional engineer.

Another view of the attributes required by an engineering manager can be obtained from the IEAust 1993 National Competency Standards for Professional Engineers (IEAust 1993). The standard defines 11 ‘units of competency’, each divided into ‘elements of competency’, and further divided into ‘performance criteria’. (See Chapter 9.) Amongst the 11 identified units of competency there are found:

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

Within these units of competency, the defined elements of competency include:

- Follow an accepted code of ethics;
- Plan, organise, direct and control tasks, people or resources;
- Perform economic, financial, legal, marketing and business management;
- Manage human resources;
- Train and develop subordinates in the work-place;
- Apply project management principles;
- Apply self-management principles;
- Communicate effectively in the English language;
- Present, report on and advocate engineering ideas; and
- Prepare, comprehend and communicate engineering documents.

Engineering Management Studies in Australia

As far back as 1968 it was identified that, “In all phases of practice in the profession the technical work is coupled, to a greater or lesser extent, with engineering management.” (Lloyd1968). A 1972 survey of 1426 practicing Australian engineers found that 92% of respondents indicated management studies should be included at the undergraduate level (PE Consulting Group 1972), and yet a
1979 review of the Australian engineering workforce still found a wide variation and general lack of management studies in Australian undergraduate engineering courses (Lloyd et al. 1979). Efforts during the 1980s by the IEAust National Committee on Engineering Management to introduce a mandatory component of management studies into undergraduate courses did not succeed (Young 1991).

A submission by the Association of Consulting Engineers, Australia (ACEA) to the 1987 IEAust task force on management education observed that, most engineers were not people orientated, and that many lack communication skills. The ACEA submission proposed a need to moderate the emphasis given to purely technological subjects with an early grounding in management studies. In particular, the ACEA argued that minor increases in a small base of management course content would not be sufficient, and that:

The need is for management to occupy a place in the syllabus that places it on a par with the major technological elements. We consider that 15 per cent of total course time would be appropriate.

The 1988 Review of the Discipline of Engineering chaired by Williams extensively investigated many aspects of engineering education, including surveying both employers of graduates, recent graduates and students to determine their views on the content of undergraduate courses. From the employers’ perspective, the review found (Williams 1988):

The majority of employers judged as “satisfactory” the emphasis given to the basic sciences, the skills, knowledge and practice of the particular discipline of engineering studied, ... But they judged as unsatisfactory the emphasis given to oral and written communication skills, industrial relations and the management of people, the management of costs and resources, engineering as part of a broader business context, and the involvement with non-engineering disciplines in project work.

From a national survey of students and graduates, the review identified those components of the course with the largest discrepancy in emphasis between “what should have been covered” and “what has been covered” as, “industrial relations, management of people, management of costs and resources, written and oral communication skills, social responsibility in engineering and engineering as part of the business context”. The recommendations of the review included references to the importance of the “human side” of technology and the need for more emphasis on the items identified by employers, students and graduates above.

In 1989 the IEAust established the Task Force on Engineering Management to draft a Policy and Guidelines for undergraduate studies in management. Following a process of consultation and review with stakeholders, in 1990 the Council of the IEAust approved the Policy on Management Studies in Engineering Undergraduate Courses (IEAust 1990b and 1991c). The policy became known as the ‘10% rule’, its essence being:

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

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

1992 also saw the publication of the report Skills for the Future – Engineers and Scientists Achieving Enterprise Performance (Bates et al. 1992). This report was jointly prepared by the Association of Professional Engineers and Scientists, Australia (APESA), the Australian government Department of Employment, Education and Training (DEET), the IEAust and a number of major engineering employers. This report concluded:

Australian engineers are well prepared in engineering technology, but not well prepared for the full practice of engineering it its managerial and business dimensions.
This report also confirmed the importance of management studies for engineering students:

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

While acknowledging the different requirements of individual professions and enterprises, the report identified a general requirement for additional multi-skilling of engineers and scientists during undergraduate education, and during postgraduate education and training, particularly in the areas of:

- cross-discipline skills - such as computer systems, mathematics, materials, environmental science, etc.;
- practice skills - such as specification and contract management, planning and resource management, heritage and cultural issues, etc;
- business and management skills - such as people management, business management, finance, economics, project management, ethics, law, etc; and
- personal and interpersonal skills - such as leadership, team work, communication, analytical and creative techniques, etc.

The report recommended a reassessment of the balance between undergraduate education, and postgraduate education and training. It suggested that these three phases of professional formation should be considered more holistically, in particular, in initial undergraduate education there is a requirement for, “an appropriate balance of technology and non-technology knowledge and skills”.

In 1993 the IEAust National Competency Standards for Professional Engineers sought to identify the overall balance of knowledge, skills, judgement, ethical standards and experience required by Professional Engineers (IEAust 1993). While acknowledging the independence of higher education institutions in determining course structure and teaching methods, the prescriptive nature of the Standards provided strong guidance for course design in all areas of engineering undergraduate course content, including management. The Standards reinforced the requirement for management studies in undergraduate courses.

In 1994 DEET commissioned the Report on the Impact of the Discipline Review of Engineering. The aim was to determine the impact of the recommendations of the 1988 Williams review. The method of inquiry involved sending a questionnaire based on the recommendations of the Williams review to every Dean of Engineering in Australia. While the recommendations of the Williams review did not specifically address undergraduate management education, amongst the many results obtained from the survey, it was concluded that developing the ‘communications skills’ of students was given a high priority by institutions, and that some progress had been made (Caldwell et al. 1994). The inquiry also investigated the impact of a selection of ‘post-Williams’ factors on engineering schools. In this section the inquiry noted that there was ‘quite strong’ endorsement for the 1990 IEAust policy for management education in engineering undergraduate courses, particularly for the requirement for 10% management component in courses. Finally, the inquiry also sought comments on ‘10 major issues identified by Williams’.

On the issue of ‘non-technical [management] subjects’ the difficulties in implementing Williams’ recommendations were identified as, “Lack of time and resources”, and, “The development of communication skills requires intensive teaching methods and the reduced funding levels have presented extreme difficulties”. The level of public funding of the higher education sector in general is likely to continue to be under pressure for the foreseeable future, so any new initiatives need to be designed to be cost effective.

In 1996 a major review of engineering education in Australia (sponsored by the IEAust, the Academy of Technological Sciences and Engineering (ATSE), the Australian Council of Engineering Deans (ACED) and the Department of Employment, Education, Training and Youth Affairs (DEETYA)) was published. The report (Johnson 1996):

...is recommending no less than a culture change in engineering education which must be more outward looking with the capability to produce graduates to lead the engineering profession in its involvement with the great social, economic, environmental and cultural challenges of our time.
The report includes 14 recommendations that cover the range of issues addressed by the six task forces, including:

- reconsidering undergraduate engineering courses; and
- introducing flexibility of access to and conduct of courses.

In ‘reconsidering undergraduate engineering courses’, changes to the profession including globalisation and information technology are identified, and the requirement for a balance between, “basic science, engineering fundamentals, management and business, ethics, with attention to social, environmental, political and economic context” is reaffirmed. In ‘introducing flexibility of access to and conduct of courses’, the need to reduce overloading of curricula, accommodate alternative modes of learning, facilitate entry from non-traditional backgrounds, and recognise skills and prior learning is identified.

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

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

There was a perception that the revised policy on engineering management studies was weaker and more ambiguous than the previous 10% rule of 1991, "Does this mean that this element could be interpreted as 1% management, and 9% professional ethics and other studies?" (Young, 1998).

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

... integrated exposure to professional engineering practice (including management and professional ethics). This element should be about 10% of total program content.

It should be noted that the original ‘10% rule’ was not greeted with unanimous support by engineering schools around Australia, and that after eight years of implementation, the level of compliance with the 10% rule still varied significantly. Research by the principal author in 1999 revealed that 36% of Australian engineering schools met or exceeded the 10% requirement; 36% nearly met the requirement (8 to 9%); and the remaining 28% fell significantly short of the 10% management content requirement.

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

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

**Australian Engineering Management Academics**

While policy from the course accreditation body and other related stakeholder organisations influences the design and execution of engineering management education, a critical factor in the implementation and delivery of engineering management studies is the academic staff with the responsibility for the design and conduct of these studies. A 1998 survey of all 93 separate academic units (faculties, departments, schools) in Australia offering one or more engineering undergraduate courses sought to characterise those academic staff (regardless of the discipline area within the university that they belonged to, and regardless of their status as full-time, part-time or adjunct staff) involved in the design and delivery of management studies in undergraduate engineering courses. (Palmer 2000).

The mean respondent age was 46.7 years, with a standard deviation of 9.9 years. The range of respondent ages was 31 to 77 years. The median respondent age was 46 years. 87.8% of respondents were male, 12.2% were female. Table 8-1 shows the percentage of respondents holding a technical qualification, as well as the distribution of technical qualifications found in the general population of Australian engineering academics, and that it does not depart significantly from the respondent group (Anderson et al. 1997). Table 8-1 also shows the percentage of respondents holding a management qualification. It reveals that more than 60% of those academics involved in the delivery of engineering management studies (regardless of whether their originating discipline area is engineering, management or something else) have no management qualifications at all. This is a factor for concern. While experience of the practice of engineering management is valuable in contextualising management studies, academic rigour in the discipline area should be considered a fundamental prerequisite for those in educational roles.

<table>
<thead>
<tr>
<th>Qualification</th>
<th>Technical (Respondents)</th>
<th>Technical (General Australian)</th>
<th>Management (Respondents)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Degree</td>
<td>4.9 %</td>
<td>-</td>
<td>61.0 %</td>
</tr>
<tr>
<td>Diploma</td>
<td>2.4 %</td>
<td>-</td>
<td>0.0 %</td>
</tr>
<tr>
<td>Bachelor</td>
<td>14.6 %</td>
<td>9.5 %</td>
<td>12.2 %</td>
</tr>
<tr>
<td>Graduate Diploma</td>
<td>2.4 %</td>
<td>-</td>
<td>9.8 %</td>
</tr>
<tr>
<td>Master</td>
<td>19.5 %</td>
<td>18.2 %</td>
<td>12.2 %</td>
</tr>
<tr>
<td>Doctorate</td>
<td>56.1 %</td>
<td>68.0 %</td>
<td>4.9 %</td>
</tr>
<tr>
<td>Other</td>
<td>-</td>
<td>4.3 %</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 8-2 summarises the years of experience of respondents working in the engineering workforce, working in a management capacity and working in a lecturing/teaching capacity. The median values reported demonstrate significant practical experience in technical, management and educational areas.

<table>
<thead>
<tr>
<th>Field</th>
<th>Mean</th>
<th>Std Dev</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Median</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engineering</td>
<td>14.3</td>
<td>13.5</td>
<td>0</td>
<td>54</td>
<td>10</td>
</tr>
<tr>
<td>Management</td>
<td>10</td>
<td>8.9</td>
<td>0</td>
<td>40</td>
<td>8</td>
</tr>
<tr>
<td>Education</td>
<td>11.7</td>
<td>8.7</td>
<td>0.25</td>
<td>35</td>
<td>9</td>
</tr>
</tbody>
</table>

Using the 1991 IEAust document *Guidelines for Management Studies in Engineering Undergraduate Courses* as a model undergraduate engineering management curriculum, respondents were asked to rate their perceived importance of each of these 17 modules on a three-point scale of not important, important, and very important. Figure 8-1 shows the results. The mean response and the
standard deviation for each of the 17 elements are given (on the basis that a response of not important = 1, important = 2 and very important = 3).

Based on mean rating, respondents ranked the elements of management competency in the following order of importance; Communication skills, Project management, Supervision and leadership, Economic evaluation of projects, and Operations and quality management. Of the five elements listed above, none scored less than a 2.5 rating.

Examining the five elements ranked highest, it appears that these skills are identified as being ‘part of engineering’ (ie. Project management, Operations and quality management, and Economic evaluation of projects) or important generic professional practice skills (ie. Communication skills, and Supervision and leadership). The first five, highest ranked elements are highly practical, action-oriented activities that members of the engineering workforce may be involved in on a regular basis.

For the remaining skills, support was less strong and/or more equivocal. Continuing on from above, the list in order of decreasing mean rating was Organisational behaviour, Human resource management, Innovation, Engineering and society, Business strategies, Legal studies, Finance, Accounting, Economics, Marketing, Theories of management, and, finally, Management science. From this second list it could be suggested that the lower rating of these particular management skills is due to the more theoretical nature of the topics (ie. Organisational behaviour, Management science, etc) or that they are closely identified with other (non-engineering) professions/business functions (ie. Legal studies, Marketing, Accounting, etc).

![Figure 8.1 Perceived importance of Management Skills]

Respondents we asked to list any other management skills they considered necessary for engineers. These additional skills and the frequency with which they were reported are listed in Table 8-3. This list of skills reinforces the fact that experienced engineers are likely to find that their employment encompasses the management of people, technology and finances in a complex environment of decision making and change, with environmental and international issues becoming increasingly important.
Respondents were asked, ‘whether the most important phase for engineering management education was undergraduate, postgraduate or both?’. 12.5% of respondents indicated that the undergraduate phase was the most important, 12.5% of respondents indicated that the postgraduate phase was the most important, and 75% of respondents indicated that both the undergraduate and postgraduate phases were important. Almost 90% of respondents indicated their belief that engineering management education should be included in undergraduate studies.

One clear indication that management skills remain crucial for engineers post graduation is the number of engineers that seek postgraduate studies in management. In the United Kingdom 32% of MBA students are engineering graduates (Hegarty 1996). In Australia the largest MBA program is one designed principally for engineers and focussed on the management of technology (Ashenden and Milligan 1999). If the acquisition of formal management qualifications is so important for practicing engineers, it must be even more so for those academics involved in the design and delivery of engineering management study programs.

The research cited above indicates that while more than 86% of Australian engineering academics hold a technical qualification of Master level or greater, barely 17% of Australian academics involved in undergraduate engineering management education hold a management qualification of Master level or greater. There appears to be a strong and pressing need for Australian academics involved in engineering undergraduate management education (irrespective of whether their discipline area is technology or management) to upgrade their academic qualifications in the field of management.

The subject area of engineering management, by its nature, incorporates an intersection of technology and management. One possible option (that is employed by many engineering schools) for the injection of academic rigour while at the same time maintaining an engineering context for management studies is the joint development and/or delivery of these study programs by academic staff from both engineering and management/business faculties. Relevance of management in engineering practice must be paramount, and any temptation to hand over the management content of engineering undergraduate courses to service teaching from management faculties should be resisted. Most engineering undergraduates take some time to appreciate the importance and relevance of management to engineering practice, and there is nothing that extends this period further than the presentation of management studies in a manner that is theoretical and abstracted from the context of real engineering practice.

**Table 8-3 Other management skills identified as important (frequency mentioned in parenthesis)**

<table>
<thead>
<tr>
<th>Skill</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time management</td>
<td>(5)</td>
</tr>
<tr>
<td>Teamwork</td>
<td>(3)</td>
</tr>
<tr>
<td>Technology management</td>
<td>(3)</td>
</tr>
<tr>
<td>International business</td>
<td>(3)</td>
</tr>
<tr>
<td>Industrial relations</td>
<td>(3)</td>
</tr>
<tr>
<td>Cross-discipline interaction</td>
<td>(2)</td>
</tr>
<tr>
<td>Ethics</td>
<td>(2)</td>
</tr>
<tr>
<td>Decision making</td>
<td>(2)</td>
</tr>
<tr>
<td>People skills</td>
<td>(2)</td>
</tr>
<tr>
<td>Change management</td>
<td>(2)</td>
</tr>
<tr>
<td>Lifelong learning</td>
<td>(2)</td>
</tr>
<tr>
<td>Networking</td>
<td>(1)</td>
</tr>
<tr>
<td>Supply management</td>
<td>(1)</td>
</tr>
<tr>
<td>Dealing with customers</td>
<td>(1)</td>
</tr>
<tr>
<td>Negotiation</td>
<td>(1)</td>
</tr>
<tr>
<td>Logic</td>
<td>(1)</td>
</tr>
<tr>
<td>Problem definition</td>
<td>(1)</td>
</tr>
<tr>
<td>R&amp;D management</td>
<td>(1)</td>
</tr>
<tr>
<td>System dynamics</td>
<td>(1)</td>
</tr>
<tr>
<td>Information technology</td>
<td>(1)</td>
</tr>
<tr>
<td>Systems approach</td>
<td>(1)</td>
</tr>
<tr>
<td>Public relations</td>
<td>(1)</td>
</tr>
<tr>
<td>Maintenance management</td>
<td>(1)</td>
</tr>
<tr>
<td>Environmental management</td>
<td>(1)</td>
</tr>
<tr>
<td>Strategic management</td>
<td>(1)</td>
</tr>
<tr>
<td>Cost estimating</td>
<td>(1)</td>
</tr>
<tr>
<td>Risk management</td>
<td>(1)</td>
</tr>
<tr>
<td>Media relations</td>
<td>(1)</td>
</tr>
<tr>
<td>Management of design</td>
<td>(1)</td>
</tr>
<tr>
<td>Contract management</td>
<td>(1)</td>
</tr>
<tr>
<td>Cost control</td>
<td>(1)</td>
</tr>
<tr>
<td>Cybernetics</td>
<td>(1)</td>
</tr>
<tr>
<td>Report writing</td>
<td>(1)</td>
</tr>
<tr>
<td>Forecasting</td>
<td>(1)</td>
</tr>
</tbody>
</table>
Undergraduate Management Education Beyond 2000

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

It is noted that the new IEAust Manual for the Accreditation of Professional Engineering Courses (IEAust 1999b) contains the statement that universities seeking accreditation of professional engineering courses will be required to have in place a quality management system that encompasses, amongst other things:

- Substantial participation by practising professional engineers, and leading employers of engineering graduates, in the engineering school’s forward planning and in its processes for ensuring educational quality, including assessment of graduate performance.

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

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

- It is clearly recognized that many engineers progress into managerial and top executive positions in industry and government. For such individuals the foundation should be laid in college for an understanding of human relationships, the principles of economics and government, and other fields upon which the engineering manager can build (Grinter 1995).

- Engineering Faculties should. . . emphasise design, problem solving, the impact of engineering on society and the environment, communication, teamwork, leadership and practical experience. . . (Canadian Academy of Engineering 1993).

- The real world is not as precisely defined as technical courses at school and university would lead students to believe...The varied problems that arise in daily professional life are not so restricted. They demand varied responses, with an integration of insights brought to bear from many different perspectives (technical, manufacturing, psychological, marketing, historical, economic, etc.) (Lifelong learning 1998).

Various Australian reviews and reports into engineering education (some of which are identified above) reach the same conclusion. The Australian ‘10% rule’ has been held in high regard internationally as a benchmark for management studies in engineering undergraduate courses. It would be a shame to see the issue of engineering management studies for undergraduates ‘go off the boil’ in Australia, and for its passing to go largely unremarked.
Chapter 9
Competencies and Attributes
By Clive Ferguson

Introduction
Until the late 1960s traditional university engineering education was focused on teaching the various branches of science, mathematics, engineering science and engineering applications. The approach was information driven and focused primarily on analysis and solving idealised problems isolated within a branch of engineering. Although most Australian university courses also had engineering design as a core study, frequently it also was worked with idealised problems. The final year project often was the only mechanism by which students could gain experience in synthesising the discrete elements and address real engineering problems.

Many courses failed to consider the impact of factors outside of engineering practice and related sciences. The result was that many graduates entered professional employment without sound skills in applying problem solving to real, holistic and complex situations. Recognition of the need for this approach in developing useful and productive engineers led to the broadening of the curriculum to include management studies and to give some emphasis to synthesis within engineering design. As limitations in graduate abilities became known (often by general employer surveys into graduate skills), deficiencies were ‘solved’ by including additional material (such as written and oral communication) in the ‘management’ units. Even so, in the 1999 Royal Academy of Engineering manufacturing lecture, Richard Parry-Jones of Ford Motors claimed that university engineering courses in the UK had ‘a mindset that relies too heavily on physics’ (Pullin, 1999). However, when the competency based education and training (CBET) approach came of age, many professional bodies, including IEAust, began adopting competency principles. This represents a fundamental move in focus on course assessment from content to graduate outcome, and it can be expected to create significant and far-reaching changes in the development of professional engineers at the start of the 21st Century.

Because of the failures of earlier forms of CBET, which were predominantly focused on trade skills, many educationalists understandably resist adopting this approach in the development of professional graduates. However, when the new approach is applied to professional education, it represents a fundamental shift in the approach of competency based education. When CBET is applied appropriately it should avoid the failings of earlier forms of competency approaches, as well as addressing some of the problems in traditional university engineering education. It must be noted, however, that this approach is still in a development phase.

This chapter describes the early developments of competency based education and some lessons learned from the approaches taken, and then considers the training reform agenda for the trades. That is followed by a brief description of the three main approaches to competency research that inform development of professional competencies. Focus on professional competencies gained impetus in the engineering profession during the 1990s, and then led to development of an attribute-based approach by IEAust to course accreditation. Chapter 10 then discusses a range of teaching and assessment strategies to shape learning and develop the IEAust attributes. Other significant attributes for engineering graduates and suitable teaching and assessment strategies to develop them also are considered.

Origins of Competency-based Education
Although the current use of the word ‘competency’ dates from the 1960s, the origins of competency based education and training lie in the objectives in education movement at the end of the 19th Century. The approach was based on the principles of scientific management pioneered by the American mechanical engineer, Frederick W Taylor (1856-1915), whose approach to work study and productivity improvement involved breaking down job functions into very detailed elements. His research into time study was based on four objectives of which the first two can be seen as forming the basis of the objectives in education movement:

1. Development of a science for each element of work (ie: a detailed task analysis).
2. Training, teaching and developing the worker for the specific task for which he or she was selected.

The objectives in education movement was the first of five generations of the competency/objectives movement. Work in the scientific management field developed from Taylor’s preoccupation with time to
complete a task, into method and motion study pioneered by Frank and Lillian Gilbreth who considered the time factor as only a secondary consideration. During the 1920s and 1930s this was mirrored in the second generation of the objectives/competency movement - *mastery learning*. The time factor was removed entirely and the emphasis was on demonstrating competency in detailed specific content and tasks to a set level. Interest in this approach declined during the Great Depression of the 1930s mainly because of three factors: significant decline in employment, the competing educational model - *progressive education* - developed by John F Dewey, and the decline in popularity of Taylorism. (Mastery learning returned in the 1970s.) A so-called third generation developed during World War 2 to train people in high level technical skills for the war effort. The use of programmed instruction and elements of psychology were applied to the design of vocational education and training programs. In many respects the approach was little more than an early revival of the mastery learning model.

Although parallels of some aspects of competency-based education and training with the scientific management movement are clear, some researchers consider the first three generations to be ephemeral, and regard the post World War 2 *behavioural objectives* movement as forming the real start of competency-based education. It was during this period that the word *competency* first appeared in its modern context.

The *behavioural objectives* movement focused on the intended outcomes of learning, and instructional objectives were set as changes in observable behaviour. An important feature was the desire to set outcomes that could be reliably observed, allowing little latitude in interpreting that the competency had been demonstrated. Three descriptors were involved:

- **Performance**: described behaviour the learner should demonstrate following the training.
- **Standard**: specified the minimum acceptable level of proficiency for that performance.
- **Conditions**: specified the training conditions, eg: equipment to be provided.

The fifth generation of the competencies/objectives movement is *Competency-Based Education and Training*. CBET began in the United States in 1967 when the Office of Education called for proposals for primary teacher education programs. Summarising Burke *et al.* (1975), the principles underlying the early US implementations of CBET were:

- Instructional program is based on specific competencies.
- Instruction is organised into units of manageable size.
- Instruction is arranged to suit learner needs, preferred sequence, pace.
- Progress is determined by demonstrated competence
- Learner is kept informed of his/her progress throughout the program.

CBET had its origins in US higher education. Its initial application in teacher education extended during the 1970s to engineering, dentistry, medicine, nursing, and law. This was encouraged by considerable federal and state funding into CBET research and development. However by the mid 1980s CBET was criticised as mechanistic and was in demise. There was general agreement that its failing was its use of job function analysis - often based primarily on motor skill analysis - leading to unwieldy lists of precisely specified performance based competencies. Many considered this approach to be too narrow and task-oriented to be valid.

There was little interest in the UK in CBET until the early 1980s. In 1988 it was adopted as part of the British government program to reform the system of vocational qualifications. The failings of the US version of CBET were recognised and the UK Training Agency recommended adoption of a new development method called *functional analysis*.

Functional analysis involved first determining the key roles undertaken by a competent worker at a particular level, and dividing them into distinct functions called *Units of Competency*. The Units then were broken down into assessable *Elements of Competency*. *Performance Criteria* were then determined to enable assessment of performance in each element. More recently *Range Statements* were added, recognising that satisfactory performance in a Unit or Element may vary with the context. In an extreme example, both a carpenter and a surgeon may be highly skilled in using a handsaw, but the context in which they use this skill is very different!

The functional analysis model of CBET was adopted in Australia as part of the training reform agenda and was recommended to bodies developing competency standards.
General Competency Agenda

The training reform agenda, initially driven by changes in industrial relations, became an Australian national training policy developed with agreement from the federal, state and territory ministers with support from peak employer and employee interest bodies. It was formalised in 1992 and had five main themes:

- nationally consistent CBET standards;
- national recognition of competencies irrespective of how, when, or where learning occurred;
- a more open national training market;
- improved access to vocational education for disadvantaged groups;
- a unified national entry level training system.

As part of a national competency agenda, the set of key competencies proposed by the Finn committee (Australian Education Council Review Committee, 1991) and developed by the Mayer committee (Australian Education Council Mayer Committee, 1992) were also to be piloted over a three-year period.

Key competencies were considered to be generic competencies to start at secondary school level in the educational profiles up to Year 10, and continue in Technical and Further Education (TAFE, or Vocational Education and Training, VET) and other vocational education providers. Key competencies apply to work generally, rather than to a specific occupation or industry. Each of the themes and the key competencies had major implications in the development of CBET in Australia.

In the development of nationally consistent CBET standards there were practical advantages in national cooperation in curriculum development, such as economies of scale in supporting a well-developed course, and in matching articulation pathways. These factors were put under question in a later review, when it was argued that CBET permitted a diverse curriculum and that a national curriculum was unduly restrictive. A compromise in the TAFE sector allowed a proportion of the curriculum (about 20 per cent) to be tailored to local requirements.

The national approach to competency recognition brought a National Framework for the Recognition of Training in 1992. This included provision for articulation and credit transfer together with recognition of prior learning, and course accreditation including the registration of private providers. The Australian Qualification Framework (discussed in Chapter 5) was set up to establish a nationally consistent set of qualifications from senior secondary certificates up to doctoral level, to promote public recognition of various qualification standards.

The open national training market was intended to provide a fair competitive market for public and private providers of post compulsory education and training services. It was argued that this would increase individual empowerment and freedom of choice, but it was recognised that this objective needs to be balanced with issues of educational quality assurance and fair participation. But effective management of these issues requires a regulated market.

Initially, implementation of the training reform agenda was restricted because of the limited numbers of TAFE and industry based trainers with knowledge and skills in delivery and assessment of CBET. A rapid staff development program in CBET was crucial to the successful implementation of the agenda. The National Competency-Based Learning Project found high staff training demands in all aspects of CBET. Initially the National Training Board was charged with the responsibility of endorsing national competency standards but that was later reduced to the maintenance of a register.

Origins of the movement in the TAFE sector brought the criticism of a narrow focus on competencies. Higher education and the professions rejected the narrow task-based focus, claiming a distinct difference between the basic skills of a trades person in comparison with the cognitive and diagnostic skills of a professional. In 1993 the Australian Vice Chancellor’s Committee (AVCC) expressed concerns over the integrity of university education, as cited by Bowden and Masters (1993):

> Unless very sensitively handled, the specification of sets of competencies required from university graduates can threaten the integrity of university-level education. Such specification distorts courses and curricula by giving undue weight and significance to attributes removed from the necessary, if less measurable, intellectual context in which they must be embodied.

In the same year an article in Financial Review stated that the Business-Higher Education Round Table wanted a clear distinction between the goals of universities and 'technical education institutions'. Mayer, as cited by Bowden and Masters (1993) put it this way:
... with universities primarily oriented towards the extension of knowledge and research and the technical education institutions primarily concerned with applied trades ... The value of greater breadth in undergraduate education was very clearly seen by several chief executive officers who argued strongly that as employers they wanted their new graduate employees to have clearly trained minds and high-level intellectual abilities rather than specific skills or vocational training.

As a result, the federal government assured the universities that they would not be required to implement CBET. However, under the guidance of the National Office of Overseas Skills Recognition (NOOSR), many professional bodies, including IEAust, produced their own competency standards.

**Competency Research**

Including CBET, three main areas of competency research and development informed the professions in the design of competency standards.

1. **Competency Based Training**

   As seen from the historical development of CBET, the competency based training (CBT) model is directly performance based. Early concepts of CBT began essentially with a job analysis from which an activity analysis was derived. From this, competency standards were developed. The philosophy was that if a person performs competently there is no need to be concerned with what he or she knows: underlying knowledge could be inferred directly from performance.

   The reason the competency based movement failed in the early 1970s was essentially the same as for the objectives in the curriculum movement forty years earlier. In both, stated objectives were derived from an activity analysis, and the volume of narrowly specified tasks made this analysis unwieldy. The response to this by the UK Training Agency in the 1980s (and Australia in the 1990s) broadened the definition of competence by adopting the functional analysis approach. As outlined above, analysis of employment functions rather than narrowly specified tasks and outcomes resulted in development of Units, Elements, Performance Criteria, and Range Statements. Jessop (1991, p.129) commented:

   The dangers of a narrow specification of competence or outcome are now well recognised. The new competency based movement is attempting to go back to fundamentals and look at what is really required for successful performance or the achievement of successful outcomes in any field of learning. ... There would be no intrinsic reason why the specification of outcomes should be narrow.

2. **Generic Competencies**

   The concept of generic competencies is more abstract: the personal qualities, characteristics and abilities that differentiate between average and excellent performers. Various surveys of employers of graduates (eg: Burtles, 1992) indicated dissatisfaction with a range of generic competencies observed in their graduate employees. Problem areas included written and oral communication skills, time management, ability to work in a team, and the skills of analysis and problem solving.

3. **Cognitive Competency**

   The concepts discussed above link competencies directly with performance, but the third research area, cognitive competency, seeks to distinguish competence from performance. The earlier approaches essentially were behaviourist in their focus, but much of what makes a person competent lies beneath the behavioural veneer. Competence, as defined in the third area of research, is concerned primarily with knowledge and ability. Performance includes other factors such as the process of accessing and using knowledge and ability, together with a range of motivational and other factors that influence response. Thus it is argued that a test of performance may not give an accurate assessment of competency.

**Attributes**

Generic and cognitive competencies link directly with attributes, or 'higher level competencies'. Attributes underpin the role performance competencies defined under CBET. Gonzi has defined 'specific competencies' (role performance competencies) as the ability to perform a task and 'higher level competencies' such as analytical skills, creative ability and critical thinking ability as those required to underpin a range of specific competencies (cited in Lloyd, 1992). Lloyd points out further that as the level of skill moves from operative level to the professional level, so the competencies required move from task specific to higher level competencies.
This is echoed by Elkin, (cited in Eraut, 1994) who labels competencies determined in the CBT model as 'micro competencies' and attributes as 'macro competencies'. In parallel with Lloyd, Elkin also suggests that there is a shift in importance from micro to macro competencies as the subject moves higher in the occupational hierarchy. These comments are a reflection of the greater need for flexibility in professional roles. Focus on attribute development rather than role performance develops professionals whose roles require them to function flexibly. In contrast, the early CBET models that focused on detailed competencies for set tasks produced a rigid skill framework that did little to develop adaptability.

Integrated Approach to Competency Research.
A National Office of Overseas Skills Recognition (NOOSR) research paper (Heywood et. al. 1992, pp. 21-8) also recognises difficulties in using either performance or attribute assessment reliably to infer competence. Heywood is critical of the Australian Competency Standards that emphasise the performance approach to assessment 'in the usual environment of the professional workplace'. The paper questions the performance approach to competency assessment in that it does not evaluate ability to transfer the demonstrated performance competency to other settings and contexts, that is, evidence of adaptability and flexibility is not demonstrated.

Researchers in the UK (Eraut, 1994) are critical of performance based CBET assessment methods for professions used in the National Vocational Qualification system administered by the Open University. They make the obvious suggestion that performance could be based on copying the performance of a mentor without the mentor passing on the underlying knowledge and understanding. Similarly in Australia, Bowden and Masters (1993) indicate three levels of competency. The first is 'observable practice', suggested as the only level adequately assessed by workplace performance. The other levels, described as underlying capacities, are 'discipline based capacities' and 'generic capacities'.

Competency Agenda for Professions
The 1993 National Competency Standards for Professional Engineers (IEAust, 1993) followed the CBET formula, although with a broader functional analysis approach based on the research into competency based training described above. Competency was defined as 'the ability to perform the activities within an occupation to the standard expected in employment' but evidence of attributes was considered an essential element in overall assessment of competency.

Heywood et al. (1992) question the value of the attribute approach by pointing out that many vital attributes can be difficult to assess and as a result are often ignored. This, in turn, brings into question the assumption that the identified testable competencies will translate into competent performance in a different situation.

To minimise the effect of the faults in each competency assessment method, the paper recommends an integrated approach involving both performance and attribute forms of assessment to infer competency. This approach was also supported in a report by Jessop (1991, p.28) for the UK National Vocational Qualifications (NVQ) program. Jessop warns that the adoption of national standards should be careful to ensure that the competencies will be transferable to a range of contexts. The UK use of 'range statements', is a measure of this transferability, and was adopted in the (Australian) National Competency Standards for Professional Engineers (NCSPE).

National Competency Standards for Professional Engineers (1993)
The Competency Standards were developed by IEAust through funding arrangements with NOOSSR under the guidance of a steering group drawn from a range of industry, professional and academic bodies. The above definition of competency in the NCSPE is qualified by the statement that, while many of the competencies can be observed directly in the workplace, others 'may be inferred from what is done in the workplace and from the demonstrated capacity of the individual to acquire and apply relevant knowledge skills and judgement within a complex and uncertain environment . . .'

The NCSPE (1993) defines competencies for the Stage 1 professional engineer: a graduate with a four-year BE degree (or equivalent) who must have 'initial Professional Engineering knowledge in an engineering discipline to provide the ability to work creatively and innovatively under guidance on Professional Engineering tasks of limited scope and complexity....' Stage 1 required demonstration of competency in seven Units:
The Standards break each Unit down into Elements and Performance Criteria, and provide brief Range Statements for each Unit. The Units for Stage 2 (experienced level) essentially were the same except that higher performance was expected for each element. For example, for an element within 'Project Implementation', the Stage 1 engineer 'participates in monitoring of construction or installation' whereas the Stage 2 engineer 'supervises construction or installation'. In addition, the Stage 2 engineer may do novel, complex or critical engineering work under limited guidance in either Professional Engineering Planning and Design or one of the elective Units.

In 1994 the IEAust published parallel sets of Competency Standards for Engineering Technologists and Engineering Associates. The structure and approach to competency definition were similar to those for professional engineers, and occupational differentiation was achieved in the range statements by specifying the benchmark qualifications for each occupational category, and by selective use of words denoting level and scope of performance.

**National Generic Competency Standards (1998)**
The Standards in 1993/94 differentiated between Stages 1 and 2 for each occupational category by defining limits of responsibility and by specific use of defined words and expressions. People unable to understand these subtleties found differentiation difficult. The revised 1998 standards define Stage 2 as the benchmark. The IEAust National Generic Competency Standards (1998) contain the National Generic Competency Standards for:

- Professional Engineers Stage 2 and Advanced Stage Engineer
- Engineering Technologist Stage 2
- Engineering Associate Stage 2

- **Stage 2**: For engineers, technologists or associates with experiential formation from Stage 1 in a specialism and field of activity, people are considered to be 'experienced' and thus capable of working autonomously under general direction on normal work for the category, but when carrying out particularly difficult work, ie, more complex or critical work, they do so under limited guidance.

- **Advanced Professional Engineer**: For engineers beyond Stage 2 the Professional Engineer exercises full professional autonomy and demonstrates a capacity for leadership of change, innovation and creativity in professional engineering work. There is demonstration of the ability to appreciate the wider context of engineering in social, organisational, and economic terms. Work may have significant corporate impact, and will therefore require skills in business, planning and supervising the use of all resources, and involvement in industrial relations issues.

At Stage 2 candidates must demonstrate ability to work independently in the normal engineering work for the occupational category. The definitions of Units, Elements and Performance Criteria for Stage 1 in each occupational level are the same as those for the corresponding Stage 2, but the evidence required of those seeking to be assessed for entry to occupational categories is not expected to reflect the experiential knowledge, understanding, or the analysis and synthesis capabilities, exhibited by an 'experienced' practitioner.

The definitions of competency in the 1998 Standards for engineers were more comprehensive than in 1993, with more informative Range Statements that set the context on matters relevant to the occupational categories, identified mandatory and elective aspects to be demonstrated, and provided guidelines on differentiation of the three occupational categories. For each occupational category there were three Core Units and seven Elective Units, denoted by the prefixes in the table below. Candidates in each Occupational Category were expected to demonstrate the three Core Units and two Elective Units for that category:

<table>
<thead>
<tr>
<th>Occupational Category</th>
<th>Core Unit Prefix</th>
<th>Elective Unit Prefix</th>
</tr>
</thead>
<tbody>
<tr>
<td>Professional Engineers</td>
<td>PC (3)</td>
<td>PE (2)</td>
</tr>
<tr>
<td>Engineering Technologists</td>
<td>TC (3)</td>
<td>TE (2)</td>
</tr>
<tr>
<td>Engineering Associate</td>
<td>AC (3)</td>
<td>AE (2)</td>
</tr>
</tbody>
</table>
For professional engineers the Units of Competency are:

**Core Units**
- PC1 Engineering Practice
- PC2 Engineering Planning and Design
- PC3 Self Management in the Engineering Workplace

**Elective Units**
- PE1A Engineering Business Management or PE1B Engineering Project Management
- PE2 Engineering Operations
- PE3 Materials or Components or Systems
- PE4A Environmental Management or PE4B Investigation and Reporting
- PE5 Research, Development and Commercialisation

The level of performance in the 1998 edition was set much higher than in 1993, with consequences considered further in Chapter 15. In the Core Units, applicants were required to demonstrate all Elements and the majority of Performance Criteria. For the Elective Units, the Range Statements provided guidance as to which were mutually exclusive, and how many and which of the Elements were mandatory. The wording for Units and Elements was the same for Engineering Technologists, but the wording in Performance Criteria and the Range Statements and Evidence Guides differentiate the two categories. The wording for some Units differed for Engineering Associates, and differences in Performance Criteria and the Range Statements and Evidence Guides differentiated the occupational category.

The 1998 edition did not provide explicit guidelines for Stage 1. For assessment for CPEng, the IEAust assessment process requires self-assessment, presentation of a Practice Report, and attendance at an Interview. The Interview normally is performed by an Assessment Panel comprising an assessor and two interviewers: one from the candidate's specialism, and one from the candidate's field of activity. Assessment panels are encouraged to take a holistic approach. A similar approach is taken for Technologists and Associates.

In recognition of the need for a process of continuous development, a revised edition was published in ring binder format (to easily accommodate anticipated changes) the following year (IEAust, 1999a). Changes in the revised version were minor but included a more developed competency based definition of a professional engineer and replacement of the title 'engineering officer' in earlier drafts with the title 'engineering associate'.

**Generic Attributes for Graduate Engineers**

The National Competency Standards for Professional Engineers provided a new focus for the initial professional development of engineers post-graduation. The Standards follow the CBET model and thus are behavioural. The 1993 Standards described Stage 1 in terms of professional engineer graduates directly from university, thus they had implications for the design and conduct of engineering degree courses. However, the main thrust of the 1997 IEAust course accreditation manual was directed towards the development of attributes (IEAust 1997). These were based on the recommendations of the 1996 Review of Engineering described in chapter 5 (Johnson 1996) with minor changes including the addition of “business responsibilities (including an understanding of entrepreneurship and the process of innovation)”.

The overall assessment of professional competence at graduation was expected to follow an integrated approach. After two accreditation sessions it was realised that this radical change was difficult to implement in one move. Over the next two years, only a few engineering schools were assessed for accreditation before the whole process was again reviewed. A new greatly enlarged accreditation manual was issued at the end of 1999. This document recognised the need for a process of evolution and took a step back from the radical approach of the previous accreditation manual. Interestingly, the minor changes to the attribute recommendations of the Review of Engineering were also eliminated. Further discussion on the 1999 Manual for the Accreditation of Engineering can be found at the end of Chapter 5.

Table 9-1 lists attributes set out in the 1999 IEAust course accreditation manual. However, in addition to the 1996 Review of Engineering, there has been considerable debate over the last decade over the attributes required by graduates generally, and graduate engineers in particular, to function effectively in the workplace. Recent literature in Australia and the UK lend support for the requirements expressed, either for graduates in general or for professional engineers in particular. However the IEAust course accreditation manual is not exhaustive in a list of desirable attributes to be developed in engineering courses. In addition to the attributes in Table 9-1, others identified include: critical thinking, intellectual curiosity and independent thought, and making judgements, accessing and managing information, time management, language skills, broader engineering education, as well as business skills, entrepreneurship.
and innovation as expressed in the 1997 accreditation manual. Additional attributes that could be included may be: ability to sense when a design 'looks right', that design figures 'are in the right ball park', dynamic and 3D visioning ability, computer skills, and political awareness.

Table 9-1
Attributes of Graduate Engineers: IEAust Accreditation Manual 1999

<table>
<thead>
<tr>
<th></th>
<th>Ability to apply knowledge of basic science and engineering fundamentals.</th>
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<tbody>
<tr>
<td>2</td>
<td>Ability to communicate effectively, not only with engineers but also with the community at large.</td>
</tr>
<tr>
<td>3</td>
<td>In-depth technical competence in at least one engineering discipline.</td>
</tr>
<tr>
<td>4</td>
<td>Ability to undertake problem identification, formulation and solution.</td>
</tr>
<tr>
<td>5</td>
<td>Ability to utilise a systems approach to design and operational performance.</td>
</tr>
<tr>
<td>6</td>
<td>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.</td>
</tr>
<tr>
<td>7</td>
<td>Understanding of the social, cultural, global and environmental responsibilities of the professional engineer, and the need for sustainable development.</td>
</tr>
<tr>
<td>8</td>
<td>Understanding of the principles of sustainable design and development.</td>
</tr>
<tr>
<td>9</td>
<td>Understanding of professional and ethical responsibilities and commitment to them.</td>
</tr>
<tr>
<td>10</td>
<td>Expectation of the need to undertake lifelong learning, and capacity to do so.</td>
</tr>
</tbody>
</table>

It is evident that there remains potential for further research in this approach to competency-based education and training. The adoption of the attribute focus in the accreditation of university engineering degree courses represents a fundamental shift in focus from course content to course outcome. If the approach were to be developed and seriously applied in the accreditation process, there is potential for significant and far-reaching change in the education of professional engineers. Most significant in this is the need for careful consideration of teaching and assessment strategies, addressed in the next Chapter.

Notes to Chapter 9

Chapter 10
Teaching Strategies to Develop Professional Attributes

By Clive Ferguson

Introduction
Towards the end of the 20th Century, factors such as digital technology, growth and economic impact of the creative industries, downsizing of large corporations and growth in the number of small enterprises radically changed the engineering work place. For the future relevance of the profession it is essential that universities respond to the demand for professional engineers who can make significant (and professionally sound) contributions in the New World. With reduced economic contribution from minerals and agriculture, this is critical for the Australian economy. However, although the needs of the main stakeholders in Higher Education are for quality teaching and learning, during the latter half of the 20th Century university academics were increasingly employed for their research potential in their specialised field. University prestige became directly linked to research output, pushing the teaching role to second place.

From the late 1980s there has been significant interest in engineering education research. In 1988 the Australasian Association for Engineering Education (AAEE) was formed as a technical society of the IEAust to disseminate engineering education research and ideas. It gained strong financial support from the Australian Council of Engineering Deans. Similarly, in the US the reduction in funding of space program research, following the end of the cold war, resulted in a number of engineering schools turning their attention to engineering education research. This interest was soon reflected world-wide. In the mid-1990s UNESCO supported the Australian based International Centre for Engineering Education (USICCEE). At about the same time the Australian Federal Government created the Committee for the Advancement of University Teaching (later the Committee for University Teaching and Staff Development) to fund education research throughout the university sector.

From the early 1970s employers increasingly voiced concern over deficiencies in various attributes of their graduate employees. However one outcome of engineering education research has been the development of a range of teaching methods to form suitable professional attributes. Many of the attributes defined were not as new as their authors believed, but the processes of analysing, documenting and reporting these activities facilitates a more informed and widespread adoption and development of a range of educational strategies significant to the competency agenda discussed in Chapter 9. Most of these strategies have also been the subject of educational research for other professions.

To meet the requirements of the 1999 IEAust accreditation manual a wider adoption of the newer strategies and more thoughtful use of the conventional strategies will be necessary. However, few university lecturers receive instruction even in basic teaching skills, so it is not surprising that the IEAust had difficulty implementing the 1997 requirements and had to resort to an incremental approach. The problem is compounded by increased class sizes and an alleged drop in minimum entry standards because of expansion of student numbers from the late 1980s. Issues of teaching expertise and the status of the teaching role in higher education were recognised in the UK by Dearing (1997). An outcome was the UK government funded start-up of the Institute for Learning and Teaching to bring professional equivalence (including accreditation of professional development programs and courses) to the teaching aspect of the university academic's role. However strong vocal opposition and reluctance to join the Institute by academics of the pre-1992 research-focused universities confirm the prevailing negative attitude to the teaching role. Similar issues were discussed in Australia and the US, but no significant actions resulted. A further problem in adopting new teaching strategies aimed at competency development is the excessive time demands they can place on already overworked teaching staff, both in course organisation and assessment. Unless this is addressed, the strategies will be unworkable.

Effective assessment and deep learning approaches are essential elements in teaching the wider range of attributes without significant erosion of essential engineering attributes such as in mathematical analysis of engineering science problems. We discuss these issues before investigating the suitability and effectiveness of a range of teaching and assessment strategies in developing the 1999 IEAust accreditation attributes. We then investigate teaching strategies for other attributes of increasing significance to professional engineers.
The Formative Role of Assessment

Assessment should be symbiotic with the teaching process, at least in its role of shaping the learning process - its 'formative' role. It is the most powerful driver of learning for most students who recognise assessment as a continuous and important component of their learning process and adjust their attitude and learning strategies to suit (Gibbs, 1994, p.152). Golding et al. (1996) go further than this in suggesting that assessment also shapes the content of teaching as well as learning. This principle was taken to the ultimate by Bloxam and Heathfield (Gibbs, 1994, p.173), who redesigned units by letting the assessment completely drive the androgy (the act, process, or art of imparting knowledge and skill to adults). They first determined the learning outcomes for each unit, and planned assessment tasks in which the students underwent a range of activities to achieve these outcomes. The units were then designed around the assessment tasks. This is closely linked to the concept of 'criteria based assessment' discussed later.

The role of assessment in the learning process is known as the formative aspect of assessment. Its role in shaping learning has become more apparent as a result of educational research over the last 20 years. This chapter considers the formative aspect of assessment as an essential and integral part of teaching strategies. The summative role of attribute assessment is also discussed briefly at the end of the chapter.

It is important to distinguish the summative and formative roles of assessment from the currently accepted definitions of summative and formative assessment. Summative assessment is graded assessment (even if only graded as pass or fail). Formative assessment is advice or feedback but does not contribute marks to the final result. The motivation to accomplish a formative assessment task is intrinsic - satisfaction from the task itself. However, because most students need to balance time for education with work commitments, summative assessment is usually required to motivate them. Thus, all assessable tasks should contribute realistically to the final mark (summative assessment) but be carefully considered for their formative role in developing the desired competencies. Students will engage more in the tasks and gain greater educational value if they can also get intrinsic value from the task.

Surface and Deep Learning

The issue of surface versus deep learning (or learning with understanding) is fundamental to the IEAust attributes as well as the integrity of university education. Students who engage in surface learning aim to avoid failure with minimal effort. Inappropriately, the common strategy is rote learning. It is an atomistic approach in which students focus on isolated facts and fail to see the relationship among the information. Rote learning is used to reduce content, not to understand it and is usually short term. Often the material is forgotten before starting the next unit of study, leaving the student at a considerable disadvantage in follow-on units. It also creates negative attitudes to learning such as boredom and leads to under achievement by the student.

Traditional pre-university education methods are heavily entrenched in this approach. There is concern that students also start university courses with the surface approach to learning, particularly through foundation units that present wide ranging detail and are assessed to test disparate elements of knowledge (Beswick and Ramsden, 1987). This sets up the expectation of the surface learning approach and a lack of early and relevant feedback may result in the student having no reason to believe that this approach is inappropriate.

In contrast, deep learning is a holistic approach. Students engaging in deep learning seek an understanding of the meaning of what is being learned. It involves the integration of ideas and concepts. This requires detailed information to be organised in a meaningful way, that is, placed in context and perspective rather than in an arbitrary way. Given a well-structured knowledge base, experienced deep learners will have the skills to do this for themselves. However most students will benefit from guidance, encouragement, and support to help them develop these skills. Concept mapping - a procedure to diagrammatically represent the relationships between concepts - is one tool in portraying the knowledge base. The structure of the assessment task is a key element in providing guidance.

Cognitive processes in learning with understanding are illustrated by the process of handling conflict when there is a perceived mismatch between new information and what is already known. One way is to modify the signal to fit what is already known. Another is to change the 'cognitive map' to accommodate the new information. The highly curious - the deep learners - are loath to do either and develop investigative techniques to produce an optimal resolution of this conflict. However, they not only relate...
the different aspects of the information with one another but through reflection they relate the different aspects to their previous studies and personal experiences. To encourage deep learning the teaching program should provide suitable experiences to reinforce this. Carefully planned laboratory experiments and other hands-on experiences and activities provided in the delivery of the unit can do this if provided at the appropriate time in the students learning cycle. Teachers can also support and encourage the reflective experiences of the students by bringing relevant reflections of their own professional experiences into class discussion.

Deep learning is necessary for effective development of most of the attributes mentioned in Chapter 9. Among the most obvious are those involving high order cognitive skills such as analysis and reflection, critical thinking, problem solving, in-depth technical competence and in providing the foundations for lifelong learning. Deep learning is also necessary for the development of 'clearly trained minds and high-level intellectual abilities' which, according to the Business/Higher Education Round Table (Prescott, 1992), employers want of their university graduate employees, and also to place any field of study in an 'intellectual context', a concern of the Australian Vice-Chancellors' Committee (cited Bowden and Masters, 1993, p. 60).

Students’ perception of task demands strongly influences their actual study approach when handling a particular learning task. Provided that they have the appropriate learning strategies at their disposal, students will orchestrate their study to accomplish the task using the learning strategies they find most suited to the learning context. This includes a wide variety of factors such as preferred learning style, prior knowledge, experience and their expectation of the demands of the assessment. If the student perceives the assessment as passive acquisition and accurate reproduction of details, he or she adopts a low-level cognitive approach such as rote learning. When the assessment is perceived to require high level cognitive processing to demonstrate a thorough understanding, integration and application of the knowledge base, then the student is more likely to engage in deep learning. For a firm grasp of detail, rote learning is time-consuming, dissatisfying and fairly ineffective. Structured ways of helping students acquire detail should be explored. Other strategies could include providing a theoretic link, visual patterns or practical problem solving.

**Learning Style and Motivation**

Empirical research by Biggs, Ramsden and Entwistle cited by Beswick and Ramsden (1987, p.5) has demonstrated a positive correlation between measures of the deep approach to learning, and measures of intrinsic motivation. The main characteristic of intrinsic motivation is that the rewards come from participation in the task rather than as a consequence of its completion. Intrinsically motivated students get satisfaction out of learning things in depth, independently of the extrinsic rewards. Even for assessment based on recall of facts, intrinsically motivated deep oriented students wish to first understand the content. This is a strategy called 'deep memorisation'.

Extrinsically motivated students are motivated by the result of passing the assessment criteria, eg: status, future career, high income, job security, etc. Such motivators provide incentive for the surface approach. Research by Deci, cited (ibid.) has shown that in general there is a strong tendency for extrinsic motivation to suppress intrinsic motivation. Later research by Benare and Deci also cited (ibid.) suggests that the key to moderating this suppression lies in individual self respect, perceived confidence, self determination, self efficiency or personal control. An intrinsically motivated student seeks a feeling of self-fulfilment from such outcomes as a worthwhile accomplishment or pride in his or her work. The student must have ownership and feel that it is his or her own accomplishment.

Thus special effort needs to be taken to enhance the learner’s belief in his or her personal control of the learning task. This is a feature of good computer aided learning (CAL) program design that has in turn been learned from the video game industry (Ferguson and Wong, 1995). It applies equally to face-to-face teaching. The teacher must take care to increase the students sense of control over the learning task, particularly when extrinsic motivation is likely to be strong enough to suppress intrinsic motivation. If this is not done then the student may abandon the deep approach in favour of minimising strategies.

**Teaching and Assessment Strategies**

In comparing teaching that encourages deep learning with that which encourages surface learning, Sharp, cited (Nightingale et al., 1996, p.6) states:
On the other hand, (assessment) which requires the student to apply knowledge gained on the course to the solution of novel problems, not previously seen by the student, . . . cannot be tackled without a deeper understanding.

The difficulty is to provide the opportunity for students to apply their newly acquired knowledge to real and challenging problems that will develop the required competencies, give them the chance to learn in depth and test the limits of their understanding. The problems should provide significant learning experiences in themselves, provide feedback that leads the students to successful completion of the task and build positive attitudes to lifelong learning. A review of research by Biggs and Telfer cited in Gibbs, (1994, p.173) into teaching that gave evidence of deep learning showed that the most successful teaching strategies involved one or more of:

- appropriate motivational context,
- interaction with others, both teachers and peers,
- high degree of learner activity,
- a well structured knowledge base.

The most common assessment methods used in engineering schools are assignments, examinations, and projects. Problem-based learning and project based learning, are rapidly gaining popularity and can be very effective in developing appropriate attributes. They introduce a new rich variety of assessment methods. Portfolios in engineering higher education are newer, and also are anticipated to gain popularity. Selection of assessment method should depend on the skills to be developed and a mixture of methods is usually preferred. Problem-based learning and project-based learning are more tolerant of the increasing variations of background knowledge, learning styles and pace of the student than the traditional teaching and learning methods.

Reviewing the deep learning implications of each of these:-

**Assignments**

Although generally perceived as requiring a deep learning approach, the student may limit the deep approach to the minimum boundaries set by the assignment problem. The wide range of assignment tasks include essays, reports, poster presentations, calculations, designs, drawings and experiments. Those motivated to a surface approach frequently read only selected passages of background texts that seem relevant to the assignment, and often take this information out of context. Assignments should be set to ensure that they encourage deep engagement in the competencies required and be as realistic (authentic) as possible. The assignment format is perhaps the most flexible form of a assessment that can be used to incorporate elements of teaching that encourage and develop deep learning skills. The assessment criteria for each assignment should also be designed to encourage deep learning and development of the required competencies and be defined in the assignment instructions.

Often students do not have knowledge of procedural strategies, and frequently use collaborative learning to discuss them, and interact with peers and teachers. Interaction with peers also helps develop team skills. It is noted anecdotally however, that collaborative learning with peers is much less frequent in the early years of undergraduate study so strategies to encourage it should be developed.

**Projects**

Individual extended projects such as the traditional final year engineering project also provide excellent opportunities for deep learning. They meet three of the four successful teaching strategies listed by Biggs and Telfer:

- motivation (if the project has been selected by the student),
- learner activity, and
- based on a well structured knowledge base (if correctly supervised).

Individual projects also involve interaction with teachers but not with peers. Group projects complete the fourth element of successful deep learning - interaction with peers - while also supporting development of team skills. However, group projects require careful supervision to ensure that all team members fully engage in responsible roles in the project. If not, the more extrinsically motivated or less able students may leave the issues requiring deep learning to other team members and simply take on tasks based on shallow learning. The selection of tasks for each team member therefore is significant. Each student
Chapter 10: Teaching Strategies to Develop Professional Attributes

should have a task for which he or she is highly motivated and no student should be given a task outside his or her capabilities.

The difficulty of arriving at a fair mark for individuals is one of the most common reasons for not using group work for assessment purposes. Final year engineering projects (individual or group) are traditionally assessed primarily by a final project report (major component of assessment) and by an oral presentation (minor component of assessment). This activity can be used to develop a useful range of competencies such as acquisition of information, design or research skills, written and oral communication, planning, and time management, as well as extending capacity for deep learning. Projects have an essential cross-disciplinary role often involving authentic ill-structured problems.

Examinations
As discussed, deep or shallow learning is heavily influenced by assessment. Tang showed that an organised surface approach involving systematic rote learning of focused parts of the content is an effective way of studying for examinations (Gibbs, 1994). She found that deep strategies were counter-productive to passing with minimal effort. However, indirect effects showed that deep learning students were not disadvantaged, but did well in the examinations.

Rote learning for examinations depends on the student’s expectation of the examination. Under pressure to maintain good pass rates, lecturers often make their examinations predictable - either routinely similar to past examinations or tutorial questions. Students simply rote learn a set of standard solutions (a procedural skill) rather than meeting the learning objectives set. Several contemporary researchers (Dahlgren, Marton and Saljo, Ramsden, and Boud) cited by Nightingale et al., (1996 p.128) found that numerous students who did well in examinations designed to test understanding harboured misconceptions of underlying principles.

If, instead of this, the examination was set to test the student’s professional competency in being able to adapt their new knowledge to solve a wide range of problems in the subject area, a deep approach to learning should have been necessary. The examination method known as Modified Essay Question (MEQ) is one example. It consists of a structured series of questions relating to a gradually unfolding problem. Students answer the questions in the correct order and to strict time limits (each answer is collected at the appropriate time) and they are not allowed to look at future questions (which contain answers to the earlier questions). Indicating the answer to the last question at each step prevents the situation where a student makes a mistake early in the exam that affects all subsequent questions. It also acts as a feedback to the student on their previous answers.

There is somewhat conflicting research on the value of open-book and closed-book examinations. Feller, cited by Koutselini-Ioannidou (1996), carried out evaluative studies to show that closed-book examinations demonstrate only that students can do what they have been able to memorise, and that open-book testing evaluates high-level skills such as conceptualising, problem solving and reasoning. However, research by Koutselini-Ioannidou (ibid.) showed that these two modes did not measure different abilities when the examination is designed on the basis of critical thinking and other higher order skills. Achievement was higher for definition and use of terminology and for problem solving in closed book as opposed to open-book examinations, and there was no significant difference in achievement in any other category.

Traditionally, examinations have been a preferred method of summative assessment because they isolate the students from the potential of unfair external support that may be available to some students in tackling assignment based assessment. Thus, it is considered that a well-designed examination can attribute abilities more accurately. However, it should be recognised that, for many, examinations are the most stressful of assessment methods and stress tends to heighten extrinsic motivation. Further, the stress factor in examinations is known to affect the performance of students unevenly.

Problem-based Learning
Over the last decade problem-based learning has attracted growing attention in a range of vocational disciplines - particularly medicine and dentistry - although some professional bodies were initially reluctant to accept it. It is a teaching strategy to increase intrinsic motivation and thus deep learning. It forces students to grapple with realistic problems and to make their own connections between theory and practice. A problem-based learning approach is not simply the inclusion of problem solving activities to a knowledge-based unit of study. It starts with introducing students to the problems rather than to the discipline
knowledge. A staged sequence of problems leads the students to the acquisition of knowledge supported by associated learning materials and support from teachers. The timing of the delivery of learning materials and support is critical. It should be 'just-in-time'.

Problem-based learning is an ideal platform for delivering a range of attributes including, for example, development of attitudes, and particularly for holistic problem solving and creative thinking. Problem-based learning provides for integrated and authentic assessment, is often group based, and requires considerable effort to structure and create the authentic staged sequence of problems and steps in developing competencies. It is a significant departure from conventional teaching methods and, to be effective, it requires induction and training for academic staff, as well as considerable enthusiasm and commitment to make it effective. Papers have reported excellent results, but cases also have observed less trained and enthusiastic staff delivering mediocre results.

Assessment strategies are varied and depend on the competencies being assessed. Assessment methods have included oral presentations, simulated interviews, poster displays, observations of procedures and team interaction, a portfolio of solutions, working models, and/or reports. The MEQ examination method described earlier can also be considered a problem-based learning assessment method.

Project-based Learning
Like problem-based learning, project based learning consists of a series of tasks designed to develop predetermined competencies and knowledge. In a typical program the projects (usually group projects) may be selected by the students to a theme defined by the school. The selected themes are chosen to engage the students in activities that draw upon the background teaching program that delivers the required technical elements. In some cases special seminars and workshops may be arranged on a 'just-in-time' basis to address key elements of the project. Because of this, project-based learning is more focused on the educational outcomes than project units such as the final year project. But, because they involve a greater degree of knowledge integration, project-based learning is closer to the authentic professional situation than problem-based learning. In Australia a number of engineering schools have strongly embraced this approach within the last few years. Internationally there has been substantial interest in courses that offer multiple group projects. A notable example is the 'Masters for the New Millennium' project led education program of the Faculty of Mechanical Engineering of the University of Twente (The Netherlands). In this program there are six group projects in the first three years (the undergraduate program) each integrated with parallel subjects, to support the projects. There is also a major individual project in the graduate program that follows.

Portfolios
Two projects exploring the use of portfolios in engineering higher education and professional development commenced in the mid 1990’s in the UK. They were directly focused on competency/attribute development and in this they were practice based, presenting systematic and organised collections of evidence to demonstrate development and achievement of specified competencies or attributes. One project was focused on the development and assessment of engineering competencies in the workplace and the other in the development of four core SARTOR (Engineering Council, 1990) attributes in a “sandwich course” undergraduate program (Ashworth et al., 1999). In this program, although the sandwich year provided the largest source of attribute evidence, the portfolio period covered the full degree course and was well supported throughout by tutorials and written guidelines. In addition to providing a major focus for the students on the development of the defined attributes, the portfolio strategy should engender the habit of reflective continuing professional development. A downside of this teaching strategy is that it is highly resource intensive and thus more suited to small groups.

Teaching and Assessment to Develop Professional Competencies.
Traditionally assessment in engineering schools has focused on the summative evaluation of the power of students to recall, sometimes in the context of mathematical skills and analysis directly relating to the limited discipline of the subject being taught. In developing their NOOSR 'Guide to the Development of Competency Standards for the Professions', Heywood et al. (1992):

recognises the current universal practice of the inference of performance competencies implicit in the ability to pass examinations and obtain qualifications. It is obvious, of course, that such demonstration of a knowledge base may not necessarily be translatable into competent professional practice in the work place, and up to the present the employer or client has tested that inference in the work place.
The IEAust course accreditation attributes, discussed in Chapter 9, require development of a much broader range of attributes than before. However, a holistic view of the IEAust attributes shows a degree of commonality in the generic attributes that underpin them. Many of the IEAust attributes can be developed and assessed by changing or modifying the teaching and assessment strategies used in delivering the knowledge base, and suitable strategies also can develop a deeper understanding. However other attributes add directly to the content load of an already overloaded curriculum.

Many graduate engineers feel that their 'workloads at university were so high that they did not have time to understand their courses' (Richardson, 1997). To accommodate new content, current course content must be reviewed. The selection and design of assessment tasks and the teaching program must focus on the desired learning outcomes. There must be consistency between the identified aims and desired outcomes of the study program, and the teaching and assessment methods.

One concern is that a key professional attribute may form only a minor part of the assessment for each study unit in which it is assessed. Students who enter a course with seriously deficient skills essential for professional performance may simply accept the loss of marks in these study units caused by that skill deficiency rather than feel challenged to improve. To maximise the assessment results, the students may judge that the time involved in overcoming these deficiencies may be spent more profitably in improving non-essential skills. Eventually they graduate with serious deficiencies in their professional attributes.

Criteria referenced assessment, initially developed in the 1950s, provides a strategy to overcome this. (It is also known as 'goals-based assessment' and 'standards referenced assessment'.) Criteria referenced assessment is defined as the assessment of the extent to which a student achieves each of the goals of a subject (which can be framed in terms of attribute development) against previously specified criteria. It can be used to provide a more targeted formative learning driver to develop the essential attributes by facilitating the separation of assessment of essential attributes from the 'nice-to-have'. This allows minimum standards to be set for each essential attribute before a pass can be awarded. Higher grades can then be awarded to those who achieved better standards for the essential attributes and/or the 'nice-to-have' attributes.

IEAust 1999 Accreditation Attributes (See Table 10-1)

1. **Ability to apply knowledge of basic science and engineering fundamentals**

   Demonstration of the attribute requires the supporting competence of in-depth basic knowledge in these fields. Development of a sound knowledge base is discussed in the Attribute 3: In-depth technical competence in at least one engineering discipline. The ability to apply knowledge in engineering practice is conventionally developed and assessed through a variety of methods including assignment problems, design projects, and examinations.

   One implicit skill in applying science and engineering knowledge is the ability to consider a broad range of factors. Most engineering problems are not solvable by consideration of a single specialised area of knowledge, but involve an optimum solution influenced by a number of disparate areas of engineering and science (including the mathematical sciences). Research into physics learning shows that students have difficulty in connecting abstract fundamental concepts to understanding derived from experience (Brereton *et al.*, 1995). Thus it is essential to provide mechanisms for students to integrate conceptual knowledge with practice, as they would in the engineering workplace, to reinforce deep learning and give a focus for reflection. Problem-based and project-based learning provide experiences with which to support deep learning in the knowledge base.

2. **Ability to communicate effectively with engineers and the community**

   Communication within industry can take many forms including electronic mail (e-mail), telephone, letter, memoranda, report writing, engineering drawings, charts, diagrams and oral presentations. The essential skills are written, verbal and graphical.

   **Written communication**

   In Australian higher education it is rare to find a set task having the sole purpose of assessing skill in effective written communication. Essay-based assignments are used to assess content rather than writing skills. However, separating competency in writing skills from the subject based study can increase sur-
face learning by overloading the curriculum. One approach is to ensure that students submitting essays style assignments have brief 'key point' refresher guidance on writing skills essential to the task, with direct reference to easily accessed support material. Motivation must be given by informing students of the writing skill assessment to be applied, and including instructive feedback.

**Oral communication**
The skills of presentation to a group are traditionally 'developed' solely by requiring students to make an oral presentation of the final year project. Until the 1990s most courses did not even provide any instruction or guidance on oral presentation. However, the increasing number of engineering faculties worldwide that include group projects are providing greater opportunities to develop this skill. In knowledge based courses, allocating topics to each student on which to make oral presentations and answer peer and lecturer discussion questions, supports both oral communication skills and deep learning. Success in answering discussion questions requires deep learning from the presenter and the discussion itself encourages deep learning in all students. The approach is convenient for small classes with on-campus only students.

**Graphical communication**
Numerous opportunities at all levels can provide practice and feedback in graphical communication skills through assessable tasks such as Computer Aided Design (CAD), graphs, planning charts, and flow charts. The attributes of three dimensional (spatial) and dynamic visioning ability can be developed in CAD and significantly enhanced by use of appropriately designed computer aided learning programs. There is evidence (Field, 1995) that spatial visualisation skills are enhanced by studies in descriptive geometry. The final year project should give substantial opportunities to practice written, verbal and graphical skills in an authentic setting and with feedback.

**Effective communication within the profession and the community at large**
Many graphical skills for speedy and accurate communication of technical detail within the profession have limited use in communicating with the community at large. Discipline-specific language in verbal and written communication is an efficient and accurate way to communicate specific detail with others in the same specialism, but is not suitable to communicate ideas or concerns to engineers or others not fluent in that language. Lack of empathy in the use of specialised language restricts the engineer's ability not only to inform the community and influence political decisions, it also presents problems in interacting with other engineers, other professionals and other members of the work force. For example, effective communication is essential for financing and marketing engineering ideas and projects. Students must develop communication skills to meet such situations, perhaps through occasional written assignments in discipline based units with that requirement included. The exercise would encourage deep learning by causing the student to think more clearly about the concepts involved, as well as developing empathy for non-specialist recipients of engineering communications.

3. **In-depth technical competence in at least one engineering discipline**
Technical competence requires knowledge and skill. For 'in-depth' competence, the knowledge base must be sound, acquired by a deep learning approach. Skills include procedures and techniques as well as problem solving and design that are discussed in other attributes.

**Knowledge base**
Research discussed above shows that numerous students with fundamental flaws in their understanding can pass examinations set to assess that understanding. John Biggs cited by Nightingale et al. (1996, p.128) proposed that development of learning for understanding follows five stages of increasing complexity:

1. **Prestructural**: No coherent grasp of the material. Isolated facts or skills only.
2. **Unistructural**: Mastery of a single relevant aspect.
3. **Multistructural**: Several relevant aspects mastered separately.
4. **Relational**: Several relevant mastered aspects integrated into a theoretical structure.
5. **Extended abstract**: Expertise. Material is mastered within the integrated structure and related to other knowledge domains. Student is enabled to theorise about the domain.
In learning under this model, assessment of isolated aspects of knowledge does not distinguish between students at the third stage and those at the fourth or fifth stages. Such assessment encourages surface learning: it does not give credit for the substantial deep learning necessary to move from level 3 to level 4. Assessment that encourages deep learning must assess and reward an understanding of the integrated nature of the knowledge domain. For learning for understanding in higher education, an alternative Concept Framework model is proposed, in which higher order abilities are developed and assessed, not the ability to rote learn:

- The concept framework is first outlined together with its relationship to other major knowledge domains.
- Information on various aspects and their respective relationships is then developed within that broad knowledge framework.
- Then more complex knowledge of the various aspects is developed and knowledge of its relationship with other knowledge domains is extended.

This framework keeps the learning objectives more focused and engages deep learning from the start. The 'five stage' framework and the Concept Framework require different delivery styles but assessment criteria are the same. Approaches under the Concept Framework model might vary from simply rephrasing tutorial questions, to major restructuring of units. Authentic tasks that require reasoning, problem-based learning and portfolios are amongst approaches that have been applied to develop learning with understanding. The key is to focus on the outcome and develop deep learning approaches in teaching and assessment.

Skills base
Skills may be procedural, or other skills ill-defined and difficult to specify. Ill-structured problem solving and design fall into the latter category and are considered elsewhere. Procedural skills involve carrying out a clear sequence of steps and performance depends on a combination of knowledge, psychomotor skills and attitudinal factors such as care and attention to detail.

In assessing skill there are two approaches: assessing the process, or assessing the product. Unless serious errors in carrying out the process are not easily apparent in the product, it is more convenient and time efficient to assess the product, for example, where the skills in designing and crafting are inferred from the product rather than assessment of processes used. Skill in the use of software such as computer-aided design and project-planning packages are similarly assessed. Often in cases where procedure is important, as in laboratory experiments, skills and procedures are assessed from the description in the laboratory report. For many skills the knowledge base required can be assessed separately to ensure it is soundly based on deep learning rather than limited to the minimum required for the particular task in hand. As with communication skills, the key is clear uncomplicated instruction, practice and feedback.

4. Ability to undertake problem identification, formulation and solution
Kurfiss defines problem solving as 'mental activity leading from an unsatisfactory state to a more desired goal state.' (Nightingale et al., 1996, p.40). It involves analytical skills that are amongst the higher order skills. Problem solving varies from the well-structured to the (initially) ill-structured. Well-structured problems are clearly stated with all the information needed to solve the problem available - either stated in the problem or known to the student. At the most basic level, solving well-structured problems is a procedural skill, as in correctly applying a standard method of solution such as an algorithm. Ill-structured problems are often open-ended and ill-defined, with no means of knowing when the problem is solved. They do not have all the information to make an optimum decision. Most problems encountered in professional practice fall somewhere in between.

Research exploring the differences between an expert and a novice problem solver shows that the primary difference is that experts possess an extensive and highly organised body of conceptual and procedural knowledge (which is a combination of specific facts and procedures for utilising those facts) that is readily accessed and used in combination with superior monitoring and self-regulation skills. (Nightingale et al., 1996, p.46) Thus the development of problem solving skills needs to be in association with a knowledge domain. Research by Jackling et al., also concluded that association of problem solving skills with a knowledge domain was also a requirement for the effective development and transferability of cognitive skills (ibid.). Stages in teaching and assessment for problem solving include:

1. Identify the stage between novice and expert we would like students to be at different stages in the course.
2. Identify the problem solving ability that can reasonably be expected at these points.
3. Provide support to enable them to develop an appropriate range of strategies.
4. Find suitable authentic problems to challenge the students at the right level.
5. Determine the assessment criteria, that should recognise and credit the various events in the problem solving process suggested by Hayes (ibid.):
   - Finding the problem: recognising that there is a problem.
   - Representing the problem: recognising the nature of the gap to be crossed.
   - Devising a plan: choosing a method for crossing the gap.
   - Carrying out the plan.
   - Evaluating the outcome: asking, 'How good is the result?' once the plan is carried out.
   - Consolidating the gains: learning from experience.

Marks should be attributed for demonstration of ability at each stage for the given problem. Finding the best way to represent a problem is the most critical element in problem solving. From consideration of the general problem solving process above, the detailed problem solving process (and acceptable variants) should be determined and marks attributed to each stage. The following is an example of the start of the detailed stages in a typical ill-defined problem:

- Correctly identifies the clues that indicate that there is a problem
- Identifies the further information required to get a better understanding of the problem
- Knows where to look for that information
- Demonstrates an understanding of each of the concepts, etc.

6. Provide formative feedback: identify any issue with the strategies used and suggest alternatives.

Relatively ill-defined problem based assignments within discipline based units will help develop problem solving expertise in association with a knowledge domain and encourage deep learning in it. However, most authentic real life problems, for which the graduate should be prepared, do not come tagged with ‘this is a second level fluids problem’. In real life, ill-defined problems cross domains of specialised knowledge and may go into discipline areas that are not part of the course. Although some problems can be solved mechanistically, others are complex and require a systemic problem solving approach. They are often ill-defined and may involve a range of considerations that cross the domains of the units the student has studied, and often must take into consideration factors the student has never studied.

Traditionally university engineering faculties use the final year project to give students the ability to base problem solving ability on the integrated knowledge domains of the whole course - but the potential to do this depends on the actual projects chosen by the student. Problem based assignments can be also be used to support other competencies such as developing information acquisition skills, or determining new information through experimentation. Creative thinking skills will also impact on the quality of outcome.

5. Ability for a systems approach to design and operational performance

Discipline based units study specialised elements within a profession but design is much more than just the sum of these disparate elements. 'Design professionals...deal often with uncertainty, uniqueness and conflict. The non-routine situations of practice are at least partly indeterminate and must somehow be made coherent.' (Schon, 1987, p.157) Design also requires creative skills - considered below as a separate competency.

Design can only be coherent if it is considered in a holistic way. The whole concept of the design must be considered at every stage. It is essential to consider the interaction of each design decision on the design outcome as a whole. The result of every detail change must be an improvement in performance in a holistic sense. Therefore it cannot be learned in a modular way. The systems approach to design and operational performance is a holistic approach. It is a concern for the whole rather than a preoccupation with optimising parts of components or manufacturing processes. Each system can be subdivided into a hierarchy of subsystems, each of which can be considered holistically. However the focus has to be on the whole system represented by the design or operational performance.

Often engineers are criticised for focusing too much on optimising parts of products or manufacturing processes and loosing track of the bigger picture. The approach could come from the traditional engineering course structure that breaks up the knowledge base into study units specialising in separate domains. Since the late 1960s, engineering design at various levels in engineering courses supports the integration of knowledge domains, but often mainly by classroom teaching. Schon (ibid.) gives a number of reasons why design cannot be taught wholly or mainly by classroom teaching:
• The gap between a description of designing and the knowing-in-action that corresponds to it must be filled by reflection-in-action.
• Designing must be grasped as a whole, by experiencing it in action.
• Design depends on recognition of design qualities, which must be learned by doing.
• Descriptions of designing are likely to be perceived initially as confusing, vague, ambiguous, or incomplete; their clarification depends on dialogue in which understandings and misunderstandings are revealed through action.
• Because designing is a creative process in which a designer comes to see and do things in new ways, no prior description of it can take the place of learning by doing.

The teaching of design with a systems approach involves development of a holistic focus in a 'learning-by-doing' environment. Assessable design assignments should focus on the holistic outcome, and then be broken down into the subsystems with a constant focus on the outcome. Assessment would be based on the holistic design and how each subsystem is designed objectively to contribute to the overall performance.

For example: in a group design project, the design objectives and overall concept design are first developed by group discussions and brainstorming sessions (with the supervisor as observer). Appropriate subgroups are then chosen (eg: Instrumentation, Mechanical, Electronic, Computer Systems, Market Research, etc.) and the first task of each group is to frame their own design objectives to best meet the overall objectives. As each subgroup generates new possible design concepts they confer with the other subgroups to discuss the implications on the overall design. Inter-group conferral continues throughout the project.

An alternative is to structure design tasks to be achieved on an individual basis. The tasks would need to ensure the student first identifies the holistic design and performance aims and keeps them in focus throughout the design of the various component features. However the benefits of the group approach in competency development are not restricted to the systems approach to design. According to Habeshaw et al. group project work is the ideal vehicle for the development of skills such as communication, leadership, chairing, organisation and peer tutoring (Latham, 1997). It also develops team skills.

6. Ability to function effectively as an individual and in multidisciplinary and multicultural teams with the capacity to be a leader or manager as well as an effective team member.

Team skills
Conventional university assessment focuses almost entirely on individual assessment and so works against the development of team skills. The general level of performance in a class often influences the marking scheme, leaving many students feeling that they are in direct competition with their colleagues. To encourage a team approach in group work there must be motivation towards an outcome. For the intrinsically motivated the outcome would provide the motivation in itself, but for the extrinsically motivated it must come from a combination of group and individual assessment. The group assessment provides the motivation for the outcome, but there must also be incentive for individual effort.

There are a number of teaching and assessment platforms for group work to develop team skills, including group experiments, group experiment reports and group assignments, as well as group design projects as described above. A group project could support development of skills in multidisciplinary and multicultural teams, as each group draws its members from a range of disciplines and the diversity of cultures among the students.

Leadership skills
Leadership has two dimensions: transformational and transactional. Effective managerial or team leadership is transformational, driven by high aspirations and ideals. Administrative leadership is transactional, where a reward is associated with a specified level of performance. A major factor in leadership is the personality of the individual and often good transformational leaders are poor administrators and vice versa. A dynamic transformational leader in one situation may be a poor leader in another situation. However, leadership training should provide situations suitable to enable students to understand the leadership function. The basis of transformational leadership is high order change. Strategies noted as used by top leaders (Bennis and Nanus, 1985) were:
1. Having a clear agenda (vision) and being oriented towards results.
2. Achieving meaning through communication
3. Gaining trust through positioning
4. Gaining recognition through positive self regard

All group activities have the potential for leadership development, particularly when enhanced with coaching. Positive encouragement must be given to enable the leader to have a positive self-regard. The selected leader should also be appointed by the supervisor or the team, to be recognised by the team as having the authority to lead. (It is anticipated that each student in turn will be given opportunities to lead.) As an example: group experiments and reports could make the leader responsible for directing the experiment, co-ordinating the results, arranging meetings with the group to discuss the results and writing the report.

To give the leader additional incentive to ensure a good outcome the group assessment on that experiment report should attribute considerable additional marks to the leader. (Overall the assessment is balanced if each student is given equal opportunity to be leader.) In addition, the leadership skills in the performance of the experiment can be assessed by observation. A group design project can also be designed to support leadership skills by requiring each student in turn to take control of the 'board meeting' and encouraging all students to express their 'visions' at meetings. Assessment of leadership skills is principally by observation and outcome of the activities for which the student is leader. Difficulties in the summative aspects of assessment include subjectivity of the assessor, the variability of group dynamics with respect to the chosen team members, and the variability of the student’s ability to lead in different project conditions.

The administrative aspects of leadership are procedural and can be developed using the current assessment methods of assignments and examinations in management units. However, activity based learning should also be used when possible to reinforce it. The group design project described can be used to develop administrative and organisational skills in such roles as meeting secretary.

7 and 8. Understanding the social, cultural, global, environmental, and business responsibilities of the Professional Engineer, and the need for sustainable development, and understanding of the principles of sustainable design and development

At face value these two attributes can be seen simply as adding directly to the knowledge base, as discussed in attribute 3. However, they also imply professional and ethical responsibilities in Attribute 9. They should not be delivered as isolated study topics, but carefully integrated throughout the course and reflected in all relevant topics.

9. Understanding and commitment to professional and ethical responsibilities

A commitment to professional and ethical responsibilities is an attitudinal attribute, heavily influenced by the example set by lecturing staff and made evident in study notes, class discussions, and deep study considerations in case studies, group projects and the like.

Attitudes to professional and ethical responsibilities could be reinforced or damaged by the prevailing culture in the subsequent employing organisation. But if ethical and professional responsibilities are analysed and reinforced in each appropriate study situation, the graduate is more likely to retain appropriate attitudes. Although values and attitudes are consistently identified by the professions as vital to competent professional work, there is little literature on how to assess them (Gonczi et al., 1993, p.3).

Ethical principles are best taught in an analytical manner in which students are assessed on presenting a well thought out ethical case for situations that involve ethical dilemmas. The analysis must make an appropriate balance between all the ethical considerations of the case. Often, as in real situations, there is no single correct answer and assessment should be based on the principles of problem solving (Attribute 4) rather than subjective judgement of the outcome.

10. A capacity to undertake lifelong learning

Some courses content becomes out of date quickly. Estimates in some areas hold that specialised engineering knowledge has a half life of only 3 to 5 years (see Chapter 19). In addition, the engineer is likely to have several career changes. This means that there is an increasing requirement for lifelong learning not only to update knowledge, but also for the individual to broaden or deepen the knowledge base (Ferguson and Wong, 1996) (Ferguson, 1998). Candy et al. (cited by Fuller and Chalmers, 1996) suggest that university graduates should possess the following characteristics if they are to continue learning after graduation:
• An enquiring mind, which includes a love of learning and a sense of curiosity.
• Helicopter vision, which includes a sense of interconnection of fields and breadth of vision.
• Information literacy, ability to ask questions, use and evaluate information in a range of contexts and media.
• A sense of personal efficacy, including a concept of themselves as capable and autonomous learners.
• A repertoire of learning strategies that can be used in a variety of contexts, which includes an awareness of their own learning strengths and weaknesses.

Fuller and Chalmers suggest that students who adopt a deep approach to learning are more likely to display these characteristics, and that there is little evidence that courses in learning skills have any lasting benefit. Instruction in learning skills should be linked to course content, take place in the regular classes, and include advice on when, where and why they are effective. Deep learning should lead to greater enjoyment of study, increased curiosity and development of skills in the learning process. Graduates with such attributes should be better able to evaluate suggested learning strategies and apply those most appropriate to the task. Development of the higher level competencies - such as analytical skills, critical thinking, and creative thinking - which underpin the detailed competencies, will also better support continuous professional development. Other useful skills for lifelong learning are information acquisition skills, as discussed below.

The other main issue with lifelong learning is the availability of suitable learning facilities to fit in with full time work. The opportunities are generally restricted to course units that are offered in the evenings or weekends or by intense on-campus workshops over several days. Distance education study (to be discussed in Chapter 11) opens up considerable opportunities.

Other Recommended Attributes
The following attributes are other graduate attributes listed from a variety of sources (see Notes to Chapter 9). The first two critical attributes were not among those recommended by the 1996 Review of Engineering Education, were included in the 1997 IEAust accreditation manual and subsequently removed in the 1999 manual. The famous engineers of the Industrial Revolution were great innovators and entrepreneurs with an excellent understanding of societal needs. These should be the most significant competencies inculcated in students.

1. **An Understanding of the Process of Innovation**

Innovation and its management are key elements in the creation of wealth, and business survival in the 21st Century. Peter Drucker defines 'systematic innovation' as 'the purposeful and organised search for changes, and in the systematic analysis of the opportunities such changes might offer for economic or social innovation.' He identifies 7 sources of systematic innovation:

1. The unexpected success, the unexpected failure, the unexpected outside event.
2. The incongruity between reality as it actually is and as it is assumed to be or 'ought to be'.
3. Innovation based on process need.
4. Change in industry structure or market structure that catches everyone unawares.
5. Demographics.
6. Changes in perception, mood and meaning.
7. New knowledge, both scientific and non-scientific.

These provide the 'pressure for change' needed to drive the innovative process. The next stage is to define the problem as accurately as possible, as the first stage of the creative process. The creative stage itself can be broken into a number of phases including problem definition, information retrieval and lateral thinking techniques such as brainstorming, analogies and the like. This is possibly the catalyst for the most significant change in engineering education. In the 1950s a schism developed between science/technology and the arts. The sciences encouraged analytical and procedural thinking and the arts encouraged intuition, initiative and lateral thinking. Later, the increasing content emphasis in engineering schools and the weight and type of assessment had a further stifling affect on the creative process.

Research using the Torrance test of creative thinking has shown that the use of problem-based learning develops elements of creative thinking (Stevenson, 1994). (The Torrance test for creative thinking tested fluency, flexibility, originality, and elaboration - either additional detail applied to the response, or more detailed solution.) The use of open-ended problems and problem-based learning, along with teacher support rather than criticism are common methods of developing creativity in art schools especially those specialising in Industrial Design (Field, 1995).
Possibly the best vehicle to develop innovative skills would be the structured group project that has elements of problem-based learning. This would be introduced by outlining the pressure for change, involving the students in accurately identifying the problem and developing skills in problem formulation. At this stage the structured creative process described earlier could be introduced.

2. An Understanding of Entrepreneurship
Entrepreneurship is the ability to convert good ideas into profitable commercial ventures. It is the engine of employment. The development of entrepreneurship skills in engineering undergraduate programs is significant both for their employment participation, national employment, the economy of the nation, and the significance of the profession. The 1999 Global Entrepreneurship Monitor project indicated that the level of activity is greatest for those aged 25 to 34 - in the early years following graduation. During the last 3 decades of the 20th Century, large organisations shed jobs through downsizing or closure. Some became collections of small organisations through decentralisation. Job creation is increasingly centred on small and vulnerable start-up organisations. Entrepreneurship is crucial for their survival.

In the education process, the development of entrepreneurial skills could be centred on a group business development project. Real world developments should stimulate interest in world events, as monitored through sources such as newspapers and television and radio programs. The choice of business product could be selected to involve sustainability, environmental and cultural issues and thus link with the IEAust Attribute 7. Any opportunity for involvement and support for a real start-up enterprise would add authenticity for the students.

3. Critical Thinking
Critical thinking is among the higher order skills that underpin a range of other competencies. There are close links between critical thinking skills and deep learning. According to Norris and Ennis, critical thinking is about reasonable and reflective thinking that is focused on deciding what to believe or do (Nightingale et al., 1996). They list four elements of critical thinking; reasonable thinking, reflective thinking, focused thinking and judgement.

1. Reasonable thinking relies upon good evidence leading to the best conclusions or judgements.
2. Reflective thinking examines the reasonableness of ones own and others’ thoughts. It is linked with the cognitive processes of deep learning, in that reflective thinking is also believed to be stimulated by a perceived mismatch between new information and what is already known. Reflection is the process of re-evaluating experience to turn it into learning.
3. Focused thinking is consciously directed, purposeful and not accidental. To provide that focus, the assessment process and criteria must be made clear to the students.
4. Judgement involves selecting the appropriate issues for consideration, evaluating the evidence, assessing and deciding. Issues involved include judging the credibility of the information source, the soundness of that information, identifying assumptions and valid logical analysis.

Critical thinking involves not only abilities but also appropriate attitudes, including open-mindedness, seeking divergent views and ensuring that any investigations are not biased towards a particular outcome. Problematic areas for students may be dispositions caused by ethnic, religious or gender related backgrounds, that might impair critical thinking.

The analysis and construction of argument in relation to critical thinking includes both formal and informal logic. Formal logic is deductive. If of valid form, their conclusions must follow from the premises. They start with an assumption that the statements in the premises are valid in themselves. Deep learning skills in traditional formal logic are too advanced for the early years of an undergraduate course but Venn diagrams, which are based on the rules of traditional logic, could be used instead. Informal logic is everyday spoken argument and is inductive. It involves making generalisations and the conclusions can only be probable. They cannot be established as absolutely true. Kurfiss (cited Nightingale et al., 1996) also points out that analysis of argument also provides practice in other significant competencies ‘such as reading comprehension, comparison and contrast and evaluation of ideas’. Controversial arguments also force students to address their own biases and rethink their ideas.

For critical thinking, students also need to use all the information relevant to the area of investigation. Kurfiss, (ibid. p.36) says it is limiting to divorce the teaching of critical thinking from disciplinary based instruction. If students do not have a substantial body of knowledge on which to base their enquiry, the enquiry itself becomes trivial. In parallel with theories on the deep learning approach, Kurfiss
claims that there is too much emphasis on the efficient transmission of large quantities of information that crowd out the time required to transform this information into meaningful and useful knowledge. Opportunities to increase critical thinking skills in disciplinary based units and reduce rote learned content should be investigated.

Assessment evidence on ability to think critically can be gained from a variety of assessment tasks such as open-ended questions or statements assessed by essays or reports, reflective journals, individual interviews, or literature reviews. Assessment is problematic because it is subjective. However this can be minimised by making the assessment criteria highly visible and ensuring no ambiguity exists in the question. Assessment should be based on the thinking processes rather than the outcome. Te Wiata (ibid. p.36) suggests an illustrative example:: 'imagine a test purported to test for critical thinking in medical laboratory science (microbiology). However to gain the correct answers the students need only memorise the answers….Such a test… would indicate nothing about levels of critical thinking despite its intended purpose, so is not valid.' To ensure congruency of assessment and competence, Norris and Ennis (ibid. p.37) suggest: 'The most important principle to follow in evaluating student’s critical thinking is that the evaluation itself should conform to the standards of critical thought.'

4. Accessing and Managing Information
There are numerous sources for accessing information: libraries, the Internet, government departments, professional and industry bodies, and the like. Libraries provide the traditional sources of information within universities and it has become common practice for skills in finding information from within a range of appropriate library sources (e.g. reference books, Australian standards, book collection, periodicals) to be taught by library staff. In managing information, students need to develop skills in determining the integrity and reliability of the information, as well as recording and storing the information they will need. As early as possible, appropriate assessable tasks should require their use to maintain and develop these skills and introduce students to a wider variety of sources. Project based and problem based learning, provide excellent authentic strategies for this.

5. Time Management
A study of postgraduate training outcomes undertaken by the Science and Engineering Research Council (SERC) in the UK (Burtles, 1992) found that employers were significantly concerned with poor time management skills. SERC took the approach that time management skills be developed in their postgraduate students by requiring reports to be submitted at regular intervals. However, in courses that involve assignments to be delivered by often conflicting deadlines, the need for time management in the students is readily established. The more formal time management skills of critical path planning can also be reinforced in project work.

6. Language Skills
Surveys results indicate a limited demand for foreign language skills. In many cases migrant engineers with native proficiency in the required language can meet this demand. However, to meet additional demand, access to appropriate foreign language electives may be provided. Partnership arrangements with overseas universities could allow students to gain a period of immersion in the language, and support the multicultural aspect of IEAust Attribute 6.

7. Broader Engineering Education
There is a need both for engineers with advanced skills in highly specialised topics, and there is also a need for engineers with a broad engineering education. The development of highly specialised engineers is required for such roles as research and specialist consultancy roles, but specialisation can also restrict career flexibility. There is a danger that over-specialised engineers could lose relevance part way through their career and may not have a sufficient breadth of knowledge or experience to support a career shift.

Graduates with a broader range of engineering skills have better employability, but this is also linked to the range of attributes developed. The development of higher level attributes better enables functionality at the professional level (Lloyd, 1992) and also better supports the development of new skills and lifelong learning to enable career flexibility.
The Summative Role of Attribute Assessment
The summative role of assessment refers to the standards and characteristics of successful performance required to demonstrate competence. The Australian national competency standards bodies have the role of ensuring that those who are certified as competent have that competency. For the engineering profession that body is IEAust, which must ensure that graduates from accredited courses have competence acceptable for admission to professional practice.

Traditional forms of assessment focus on assessing the knowledge students have gained in each study unit. The assessment method lets them demonstrate their knowledge in easily measured ways. The assessment criteria constitute a value judgement of the worth of these criteria. It is these values that are now being challenged by the new focus on attributes.

As a result of a 1992 NOOSR workshop it was recognised that inference of performance based on the ability to pass examinations that demonstrated a knowledge base could not necessarily be translated into competent professional practice in a workplace. The knowledge base is only one attribute required for competent performance. The Higher Education Council have classified generic skills in terms of assessment as 'some that clearly are assessable, some that could be if thought about, and some that could not' (Higher Education Council, 1992, p.25). Similarly Heywood (1992) states that 'many of the attributes of competence are readily recognisable; others are undefined, poorly understood or not even recognised'. Thus competence is intangible. It cannot be measured directly.

However it is necessary to get evidence in some form from which competence can be inferred. Assessment methods often take the behaviourist approach, using tangible overt behaviours as an indication of competency, rather than by assessing the underlying attributes. It is critical that sufficient evidence of suitable quality is collected to make a safe inference and that the subject demonstrates a consistent level of competence. Mitchell and Cuthbert, cited by Harris et al., (1995, p.162) remark that: 'meeting all the criteria for an element on one occasion is not necessarily the same as being competent (in) that element. Competence should normally be decided on an accumulation of evidence over time and preferably from different sources...'

Clearly there could be situations where an underlying attribute may have less significance in the assessed situations than on performance in another situation. Different levels of responsibility may also cause a difference at different stages of professional development. Because of this, range statements are built into the National Competency Standards for Professional Engineers (IEAust, 1993).

Competency standards are focused on defining the elements of competence required in a work role, the level of performance required for each element, essential knowledge, skills and other attributes and the context in which the competency takes place. They should also consider the elements of competence to be assessed together and define what constitutes sufficient evidence of competency. Thus assessment is an essential element in standards development. The key criteria of assessment are Validity, Reliability, Fairness, and Flexibility (VEETAC cited Harris et al. 1995, p.157):

- Validity: should ensure that the assessment assesses the competencies that it sets out to assess. For example a multiple-choice test for which the answers can be learned by rote is not a valid assessment for critical thinking. Further, competence is not only the underlying attributes but the ability to apply them to occupational tasks, so the closer the assessment to the authentic task, the more valid the assessment.
- Reliability: Reliable assessment results in consistent interpretation of competency standards and their levels from learner to learner over time.
- Fairness: No learner should be disadvantaged. The assessment must be transparent, and equitable. Fairness may be impaired if factors such as ethnicity, religion, gender, for example, affected the assessment. A clear set of standards can help overcome subjectivity, and must be based on commonly held values and have credibility.
- Flexibility: A variety of assessment approaches should be used appropriate to learner needs, and delivery modes (ie: on or off-campus).

Andressen, cited by Nightingale et al. (1996) adds the criteria of ‘strategic rationality’. Harris et al. (ibid.) describe an assessment ‘paradox’ significant to earlier discussions in this chapter. They state that traditional assessment methods are organised to ensure that the skills measured are those of the individual. However, increasingly workplaces are becoming structured so that people work in groups. Thus, ability to contribute to group performance is more important than individual performance. As discussed earlier, in assessing group work it is essential for the assessment to take into account both the overall achievement of the group (to maintain a focus on the outcome) and the individual's contribution.
Developments in competency based education and training (CBET) in the 1970s focused on setting a minimum standard, but it did not reward those who demonstrated competence well above this standard. However, in the 1980s the minimum standard concept was swept aside by a new concern for excellence. Competency levels were introduced. In the university environment this means that the current grading system will not be swept aside in the competency agenda. However there is a seductive objectivity with the awarding of marks for assessment tasks whilst for assessment that ascribes marks for a range of competencies, some level of subjectivity is always involved.

Table 10-1
IEAust Attributes (1999) and Equivalent Generic Attributes.

<table>
<thead>
<tr>
<th>IEAust Attributes (1999)</th>
<th>Generic attributes</th>
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</thead>
<tbody>
<tr>
<td>1 Ability to apply knowledge of basic science and engineering fundamentals</td>
<td>• In-depth knowledge base. (supporting attribute)</td>
</tr>
<tr>
<td></td>
<td>• Ability to integrate, synthesise and apply theoretical and experiential knowledge from a range of sciences.</td>
</tr>
<tr>
<td></td>
<td>• Problem solving</td>
</tr>
<tr>
<td>2 Ability to communicate effectively, not only with engineers but also with the community at large.</td>
<td>• Written, oral, and graphical skills. Range statement - from discipline specific to non-technical.</td>
</tr>
<tr>
<td>3 In depth competence in at least one engineering discipline or in depth knowledge base</td>
<td>• Procedural skills</td>
</tr>
<tr>
<td></td>
<td>• Ill-defined skills. (eg: ill-structured problem solving &amp; design)</td>
</tr>
<tr>
<td>4 Ability to undertake problem identification, formulation and solution</td>
<td>• Problem solving</td>
</tr>
</tbody>
</table>
| 5 Ability to undertake a systems approach to design and operational performance         | • Holistic focus  
|                                                                                        | • Design skills                                                                     |
|                                                                                        | • Creativity                                                                         |
| 6 Ability to function effectively as an individual and in multi-disciplinary and multicultural teams with the capacity to be a leader or manager as well as an effective team member. | • Team skills  
|                                                                                        | • Leadership skills                                                                  |
| 7 Understanding of the social, Cultural, global, environmental, and business responsibilities of the Professional Engineer, and the need for sustainable development. | • In depth knowledge base                                                          |
| 8 Understanding of the principles of sustainable design and development.               | • In depth knowledge base                                                            |
| 9 Understanding of and a commitment to professional and ethical responsibilities.       | • In depth knowledge base                                                            |
|                                                                                        | • Attitudes                                                                          |
| 10 A capacity to undertake lifelong learning.                                          | • Enquiring mind  
|                                                                                        | • Information literacy                                                               |
|                                                                                        | • Holistic focus  
|                                                                                        | • Deep Learning Skills                                                               |
|                                                                                        | • Learning strategies                                                                |

Conclusion
Development of attributes should be predominantly by careful recrafting the assessment and delivery to meet the new competency objectives. The attribute development structure should permeate the course with no study unit assessing an unmanageable number of attributes. Assessment methods may still be predominantly in the basic form of assignments and examinations, but with a wider range of assessment and delivery options. For example, adoption of project-based and problem-based learning may require alternative assessment methods such as observational assessment, reflective journals, or individual interviews. The critical analysis and monitoring of the attribute structure for the entire course can be facilitated by a criteria referenced assessment approach.

This approach can also be used address the concern that a key professional attribute may form only a minor part of the assessment for each study unit in which it is assessed. Whilst currently an academic staff member may identify these competency deficiencies and recommend constructive remedial action to the student, criteria referenced assessment can be used to provide the driver for the student to follow this advice. A secondary role of summative assessment is the evaluation of teaching methods. However, where the teaching objectives are changed, comparisons become invalid. Thus there will be a discontinuity in this quality control function.

In summary, the focus of the competency agenda on graduate attributes should enable development of professional engineers capable of maintaining the relevance of the profession in the new economy.
This will require more strategic use of a range of educational strategies that integrate with appropriate formative assessment. To reinforce attribute development throughout the course, course development will need a greater involvement from all teaching staff. The teaching skills and commitment needed from all academic staff will demand a reappraisal of the significance of the teaching role in engineering education.

The IEAust course accreditation manual attributes discussed in Chapter 9 require development of a much broader range of attributes than before. A holistic view of the IEAust attributes shows that many are underpinned by the same generic attributes (see Table 10.1) and several such attributes are also linked. For example, the 'ability to integrate, synthesise and apply theoretical and experiential knowledge from a broad range of sciences' is a key factor in 'problem solving'.

Notes to Chapter 10

1. As long ago as 1909, Binet, cited by Torrance (1970, p.35), observed this in French schools, but there are indications that it was similar in many countries including the UK and Australia. More recently, Beswick and Ramsden (1987) describe the (Australian) university entrance methods as based on examinations or tests for which rote learning might have been considered the appropriate method of preparation. Although in Victoria the entry assessment changed to the Victorian Certificate of Education, which includes assignment type activities, there is empirical evidence that the teaching associated with many of these activities is narrowly focused on the assessed task without providing an understanding of the principles at a level necessary for deep learning.

2. Group poster presentations, in which the presenters discuss and defend their work with peers and academics, have gained increasingly popularity as a higher education teaching strategy over the last twenty years. Research has shown that not only do they encourage deep learning and critical thinking, they support a wide range of attributes including logical and concise writing, graphical presentation, information literacy, creativity, and team skills. This strategy is also probably the best to develop peer learning - particularly if peer assessment is also involved.

3. This factor was widely discussed in the late 1990's in relation to the Victorian Certificate of Education assessment.

4. Information supplied by Tony Pearce of the Open University Vocational Qualification Centre. This project which commenced in mid 1995 was carried out by the OU at the invitation of Scottish Power who provided their engineers with suitable practice based training opportunities to support the development of their competencies to standards newly developed by the (UK) Engineering Services Standing Conference. The practice curriculum and knowledge base assessment strategies were developed by the OU who also provided regular on-site group portfolio building sessions.

5. Reluctance to remove dated curricula was recognised in 'The saber-tooth curriculum' written by Harold Benjamin in 1939 cited in (Hooper, 1971). It used the allegory of a tribe who institutionalised their learning for survival, but failed to reform their curriculum. Their curriculum dealt so well with the hunting of sabre tooth tigers that these tigers became extinct, but the tribe's young continued to be instructed in the hunting of sabre tooth tigers for various "educational" reasons - it was basic to tribal tradition, provided essential discipline etc.

6. Beswick and Ramsden report a negative example of an additional activity-based optional unit developed specifically to deliver study skills to students over a range of faculties. To overcome recognised deficiencies in the learning skills of their students, one university developed a learning skills program separate from the subject based classes and found that this led to an increase in the use of the surface approach to learning. The study skills included were written and oral communication, library skills, how to take notes, examination preparation etc. (Beswick and Ramsden, 1987, p.11). One reason given for the increase in surface learning was that the extra workload of this unit forced the students into adopting minimisation techniques to enable them to cope with the workload.

7. This echoes Einstein’s quote “the proper formulation of the problem is even more essential than its solution”.

Chapter 11
Education at a Distance

By Clive Ferguson

Historical Origins of Distance Education
Distance education was forged on the frontiers of North America and Australasia towards the end of the nineteenth century. It was more than simply a response to the vast size and sparse populations of these countries. The harshness of life in the new settlements developed a more democratic society than the Old World where education facilities for country dwellers were largely ignored and advanced education was reserved for the affluent or fortunate. Also, the strong interest in primary production and the political power of the rural interest groups in the newly developing countries created a demand to remedy the imbalance in the provision of educational facilities between city and country. Although distance education (initially known as correspondence education) is founded on the technology of printing (mid 15th Century) it also required the infrastructure of railways for fast reliable mail delivery. By late nineteenth century both the USA and Canada had transcontinental railways and each of the colonies of Australia had significant railway systems radiating from the major seaboard cities.

Some of the earliest experiments in correspondence education were for adult education. In 1890 the International Correspondence School began in the US teaching mainly business and technology. It developed to provide courses to prepare students for examinations by professional bodies and still delivers distance-based continuing education today as ICS Learning Systems. The following year a correspondence course in agricultural science was offered by an institution at Madison, Wisconsin for those unable to attend campus. However the main initial thrust of correspondence education was for primary education. The Calvert School at Baltimore, USA is usually credited with the first experiment in education of children at home by correspondence in 1905/6 (Bolton, 1986) and by 1909 correspondence education was established in Victoria, Australia, to provide for children remote from primary schools. By the early 1920s each Australian State had established similar facilities and the western and central Canadian provinces followed between 1919 and 1927 with South Africa and New Zealand a little later. Primary level correspondence education relied on the labour of the children’s mothers, few of whom had previous teaching experience and many had limited formal education. It was designed for the rural minority whose educational expectations were not especially high. At the adult education level, correspondence courses to allow Australian teachers in remote areas to complete their qualifications at a distance were introduced in 1910. In 1911 the University of Queensland became the first Australian university to enter the correspondence education field. During the 1920’s and 1930’s several Commonwealth universities provided external tuition using the same methods as those used for primary school correspondence education. The main clients were itinerant or remotely based schoolteachers and civil servants working for bachelor degrees. In Old World countries such as Britain, correspondence education developed only in the private provision of adult vocational and professionally related education. Pitman was probably the oldest provider but the British Institute of Engineering Technology was significant in preparing many engineers for the corporate membership examinations of the professional engineering institutions.

Compared with on-campus learning at even the most remote schools or universities, correspondence education was clearly second best - but preferable to no education at all. One problem was the delay inherent in correspondence communication which restricted dialogue and the flexibility to provide the timely response to individual differences in student knowledge base inherent in good proximal (classroom) teaching. However, since the early days of correspondence education, distance education has embraced a range of developing technologies to support learning.

In 1926, the Reverend Doctor John Flynn, founder of the Royal Flying Doctor Service, suggested the use of a two-way radio to support “inland” children with their schooling but it was not until 1951 that the first School of the Air was established at Alice Springs to deliver lessons as student support for correspondence education programs. In addition to radio programs with live talk back, the Schools of the Air developed educational programs which provided a variety of experiences such as home visits, and workshops and camps. They went a long way towards providing the mix of individual and group learning on which the pedagogies of conventional schooling are based.

The take up of technologies in distance based higher education was initially slow. Probably most
significant was the creation of the Open University in the UK in the late 1960’s which initially delivered its lectures and demonstrations entirely by national television supplemented by printed study notes and tutorials held outside normal working hours at technical colleges throughout the country. It heralded a start to the uptake of technology that accelerated rapidly toward the end of the 20th Century to make distance based education the most dynamic aspect of higher education. Print is still the main medium used to present core teaching material. For the student it is easy to access, note and cross-reference, is portable, robust and does not require additional technology to use. However online course delivery is now also significant. The range of technologies now used to supplement text includes video and audiocassettes, television, tele- and video conferencing, computer-based learning, and computer-based communication strategies. The main limiting factor in the use of technology in distance education is student access to enabling facilities and the associated equity issues.

Intrinsic Values in the Delivery of Higher Education by Distance Education.
From its modest late 19th Century beginnings, distance education in all its various forms is set internationally to become the dominant mode of higher education delivery of the 21st Century. The key advantages of distance education are the flexibility of time and place of study. Study material can be delivered by mail or online to anywhere in the world and can be studied when and where is most convenient for the student. As successful distance education study requires the higher level of self-discipline and motivation usually more evident in ‘mature’ students (defined in Australia as those over 21), most universities enrol only mature students into distance education courses. However, mature students provide the main growth area in higher education. They include not only those who did not have the opportunity to go to university when they left secondary school but also the increasing numbers changing career direction, studying for higher degrees or engaged in continuing professional development to update or broaden their education (Ferguson, 1998). Commercially, distance education also provides an easier mechanism into international higher education markets, and as government funding of universities diminishes, overseas markets become a critical income source.

Distance education enables students who have already embarked on a career to avoid career disruption and loss of income. Ironically, many now live within easy commuting distance of the university. For those mixing part-time study with work or family commitments, it provides the convenience of time of study as well as the flexibility of geographical movement that may be necessary if the student or the student’s partner changes work location. With increasing globalisation and casualisation of the workforce, this is becoming increasing significant. Distance education is still frequently considered second class education and yet for higher education it has its own intrinsic educational advantages as highlighted in Table 11.1.

Imperfections in the Proximal Teaching Mode
In the past there has been a tendency to focus on the few obvious disadvantages of distance education compared to proximal teaching, however proximal teaching has its own difficulties, including:

- Imperfections in either the teaching or content of the lectures. In distance education these are more easily monitored and improved by both the physical substance of the materials and the course team approach.
- Problems caused by sickness or family crisis of either the student or the teacher.
- In the second half of semester, many students skip lectures and tutorials to meet the assignment deadlines, resulting in a discontinuity in their study program.
- Timetable clashes.
- Practical difficulties in scheduling small group laboratory exercises synchronous with the study of the relevant theory.
- Often inappropriate for mature age students in pursuit of continuous professional development/lifelong learning.
Table 11.1
Intrinsic Educational Advantages of Distance Education

<table>
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<th>Interface with employment</th>
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<tr>
<td>The ability to combine study with work in the field of study provides ideal reinforcement of course content. It enables students to place the various areas of study into context and allows them to reflect on real experiences related to their studies. While “sandwich” courses are valuable in providing this through a period of suitable work based training at a suitable stage in the course, the ideal is better achieved by the combination of career-track work with relevant part time study. For most students distance education provides the most convenient way to achieve this.</td>
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<tr>
<th>Independent self paced learning</th>
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<tr>
<td>The physical separation from peers and teacher fosters an independent learning attitude in distance education students. Access to all the study materials at the start of each unit, gives them increased “user control” of the timing and order of study to suit their individual background knowledge. They can more easily recognise and redress any skill and knowledge deficiencies during the study program. This makes the study more meaningful for the student and has a positive effect on both motivation and self-confidence. It also provides the flexibility to cater for short periods of sickness, or exceptional family or work commitments. The distance education focus on learning has resulted in education being more student-centred with the lecturer seen as facilitator.</td>
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<th>Wider variety of stimuli</th>
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<tr>
<td>The level of mental stimulation produced through each of the various communication mechanisms varies with the person and significantly affects their ability to learn. For example, some may better recall information delivered aurally, others may respond better to a class demonstration. Conventional teaching favours those who respond best to a particular rather limited range. Correspondence education greatly limited that range to just the printed word (with illustrations), but the increasing variety of technologies now used in distance education has opened up a much wider range of stimuli (e.g. audio, video, interactive computer programs etc.) than conventionally used in on-campus teaching. Frequently studies introduced by one mechanism are developed and reinforced by others. This increases engagement for all students.</td>
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<th>Reduced discrimination and improved social dynamics</th>
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<tr>
<td>Physical handicaps, the stigma of repeating a unit or differences in ethnicity, age, gender, physical appearance or socio-economic status can make students feel intimidated, insecure and isolated in a classroom environment; others may be naturally reserved in a large group. These factors have a significant effect on class participation. However, the use of text-based computer conferencing, which has evolved as a significant delivery mechanism in distance education over the last decade, creates a physical separation from peers and teacher, reducing or eliminating the effect of most discriminatory factors. The facility to compose and edit communications, to provide a considered response before posting them to the group, to reread and reflect on other peoples comments, and the degree of anonymity provided by the lack of physical presence, give greater confidence to participate in classroom discussions. The result is a potential for more inclusive participation, improved social dynamics, and higher quality of discussion.</td>
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<th>Reduced environmental stress</th>
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<tr>
<td>Distance education students are spared the stress of studying in an initially unfamiliar environment and the associated travel.</td>
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</table>

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<tr>
<th>Cumulative improvement in androdogic quality of the course.</th>
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<tr>
<td>The permanent physical nature of distance education materials provides a firmer foundation for detailed course analysis and development. Their permanent physical existence is more amenable to improvement through objective criticism than lectures.</td>
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<tr>
<th>Academic staff development from working in course teams</th>
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<tbody>
<tr>
<td>Operational differences between the more established distance education universities and traditional universities are more than educational delivery mode. In the traditional university the lecturer is usually solely responsible for developing all aspects of a unit of study within an agreed loosely defined syllabus. However, the UK Open University pioneered a course team approach widely adopted by other higher education distance providers. In this, teams of lecturers, often with an educational developer and access to editors and multimedia specialists, plan, create and continually develop the units - including not only subject matter but also presentation, androdogogy and assessment. Discussion and reflection associated with the team focus on each unit of study provide continuous individual staff development.</td>
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**Continued:**
Depolarisation of proximal and distance education

Recognition of the educational and marketing benefits to be gained by the use of distance education technologies has resulted in the adoption of many of them in proximal teaching. Other technologies effectively enable face-to-face teaching over a distance. An example of this is the ‘industrial campus’ where video conferencing and on-site lectures are provided at the work site for groups of industry based off-campus students (Wong and Ferguson, 1996). Further, some of the technologies now used extensively in support of distance education were initially developed for proximal teaching. There are two distinct types of higher education distance education provider: autonomous providers which teach entirely by distance education, and ‘mixed’ or 'integrated' institutions which have both on-campus and off-campus students. Integrated institutions predominate in Australia and in these the same academics prepare and teach distance education courses concurrently with their on-campus equivalents. This facilitates quick adoption of off-campus materials or facilities into on-campus use whenever considered educationally advantageous. Similarly direct classroom feedback from the on-campus group is used to improve the off-campus program. Out of this depolarisation comes ‘flexible delivery’. The Flexible Delivery Working Party (1992, p. 47) defined this as an approach ‘which allows for the adoption of a range of learning strategies in a variety of learning environments to cater for differences in learning styles, learning interests and needs, and variations in learning opportunities’. To meet the objectives of flexible delivery a course should provide:

- Flexibility of entry and exit point, program components, modes of learning, and assessment processes.
- Learner control and choice regarding content, sequence, method, time and place of learning.
- Application of learning technologies where appropriate.
- Appropriate learner support systems and learning resources.

Approaches taken in various flexible-delivery based courses and the degree of success in meeting these objectives vary widely. Delivery mode can vary from substantially on-campus delivery to fully off-campus delivery, however at both extremes the technologies and approaches developed in distance education are significant at meeting the objectives of flexible delivery. Adoption of flexible delivery has been notably high in the Technical and Further Education (TAFE) sector. Experience in the higher education sector in Australia and in the US has shown provision of full flexibility to have difficulties. In addition to staff workload problems, students prefer structure to their course, and flexibility to select assignment and examination deadlines results in extended programs and a higher rate of non-completion.

'Distributed learning' is a similar hybrid of distance and proximal education - but without the full flexibility envisioned by 'flexible delivery'. It is rapidly gaining popularity in the US. Like flexible delivery, it can vary from (reduced) face-to-face contact enhanced by the use of a variety of multimedia technologies, to complete distance education. The Institute for Academic Technology of the University of North Carolina has defined distributed learning as:

'a learner-centered approach to education which integrates a number of technologies to enable opportunities for activities and interaction in both asynchronous and real-time modes. The model is based on blending a choice of appropriate technologies with aspects of campus-based delivery, open learning systems, and distance education. The approach gives in-

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Table 11.1 continued:
Intrinsic Educational Advantages of Distance Education

<table>
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<tr>
<th>Facilitates inter-university collaboration</th>
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<tr>
<td>Inter-university collaboration facilitated by the provision of distance based engineering degree courses can exist at a number of levels:</td>
</tr>
<tr>
<td>1. A university (under license) can use materials and facilities, developed by another university.</td>
</tr>
<tr>
<td>2. Materials and facilities can be developed and used collaboratively by several institutions.</td>
</tr>
<tr>
<td>3. A university could prescribe distance education units provided by other universities to expand its range of elective units, or replace a core unit of its own when a specialist lecturer becomes temporarily unavailable. Suitable distance education units could also be prescribed to solve on-campus timetable clashes or for on-campus students who need only one or two units to complete a degree, thus freeing them to take on full time employment.</td>
</tr>
<tr>
<td>4. A degree course developed and delivered through collaboration between two distance education providers.</td>
</tr>
<tr>
<td>5. Provision of multi-university engineering degree programs with a wide choice of distance education study units from a large number of participating Australian university engineering schools.</td>
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The IEAust through its subsidiary Engineering Education Australia has facilitated level 5, however there is scope to develop greater co-operative activity at the other levels.
Typically, a range of distance education technologies may be used to present information, activities to re-inforce learning and support discussion between students, whilst proximal activities are used to develop skills best practised in a face-to-face environment. A number of private ‘for profit’ universities and some public universities provide the face-to-face contact through a distributed network of small centres or ‘branch campuses’ each catering for 400 or so students. These are usually fully staffed with learning advisers but few other university facilities. Face-to-face teaching is often done to a script with limited degrees of interpretation to ensure consistency between campuses, although some public universities simply use broadcast video to each site. US industry is increasingly moving to this format for in-company training to minimise the cost of travel, lodging and training facilities.

Technology in Delivery of Distance Education in Engineering

Individual engineering units of study by distance education have been provided by mixed mode Australian higher education institutions for some time, but until the mid 1990s the IEAust required off-campus students to complete the last two semesters on-campus. Reservations about the suitability of an entire engineering course of distance education study units were based on the approaches and technology commonly used until the early 1990s. However the ensuing rapid advances in distance education approaches and technologies in engineering courses led the IEAust, in July 1995, to waive the on-campus requirement. Instead, institutions were required to establish mechanisms to ensure off-campus students acquired engineering practice skills, professional awareness and social responsibility. By this time the IEAust commitment to the concept of distance education for engineering degree programs had been demonstrated by its establishment of a subsidiary enterprise, Engineering Education Australia, to broker distance based engineering units from IEAust accredited university engineering degree programs. Recognising the special practical and experimental content of engineering courses, early concerns of the use of distance education delivery for engineering education included:

- Inability to provide the physical demonstrations of concepts often provided in lectures.
- The extended time difference between studying the theory and performing associated laboratory experiments at an on-campus workshop dramatically reducing the effectiveness of the experiment in reinforcing theory.
- Lack of opportunity for discussions with lecturers, interaction with peers, and access to university services such as the library.

The need to address each of these concerns created the drive to explore the potential of numerous ‘educational’ technologies both old and new. The Australian government and various philanthropic bodies providing funding for this required a continuing focus on educational outcomes.1

Conceptual course components

Video and television are often used in distance education to deliver concepts that cannot be adequately provided by text and still illustrations. They can also provide a human face and voice to the educational program. Both media have the potential to significantly improve on the lecture, as classroom practical demonstrations often disadvantage students who are not positioned directly in front of the lecturer. They are usually carefully scripted, produced and edited to ensure concepts are presented clearly and unambiguously and have the flexibility to show close-up and overview shots as required and in directions that best illustrate the concept. Unconstrained in location, they can switch views at will between (say) lecture theatre, laboratory and industry or display multiple views simultaneously, enabling ample scope for clarification and concept reinforcement.

Video is also used with great advantage in on-campus delivery. To justify high production costs a life expectancy of several years is usually required, so care should be taken to avoid including content that may quickly date. Videos have been used extensively in all education sectors and particularly in industrial training, so there is already a vast library of ready made educational videos available. Most are commercially produced.

The use of television in higher education predates video. The Open University in the UK, and many of its earlier counterparts around the world, were founded on the use of national television to deliver its lectures before video recorders became common household items. Television has the disadvantage of inflexibility in time of study (particularly as they are screened at unsociable hours), so students now often video record the programs to enable them to view (and review) the programs at more conveni-
ent times. The Open University found the requirements imposed on it by the national television broadcaster to be constraining and so focused more on the alternative media of video and computer aided learning (CAL) programs.

The current generation of CAL programs uses multimedia in the form of text, computer graphics, animation and digitised audio and video clips to illustrate concepts, and interactivity to reinforce them. Interactivity allows the user to click on interactive links known as ‘hyperlinks’ in the form of text, a graphic or animation to access further information, indicate a response or control the order of presentation. CAL was first used to illustrate concepts in university level engineering education in Canada, the UK and the USA in 1962 but over the next three decades the number and quality of CAL programs were limited. They were not used in distance education, as they were impractical to use without proximal support. However during the 1990’s advances in software, computer hardware and the development of multimedia technology had a tremendous impact on CAL.

The first major development occurred in the early 1990s when new multimedia authoring software became available enabling production of high quality user-friendly CAL programs using computer graphics, animation and hyperlinks to be economically viable for university use. Off-campus students initially accessed these through one or more high-density floppy disks and on-campus students accessed them through a university Local Area Network. Research at that time into the use of CAL programs to enhance engineering teaching (Ferguson and Wong, 1995) found:

- Appropriate use of graphics and animation are the most successful features of CAL. This is supported by previous research by Baek, (1988) which showed that in teaching a mathematical rule, graphics with text produced higher performance scores than just text, and the introduction of animation further improved the scores.

- A high proportion of first year students (93-100%) had played video games and nearly 40% were frequent players. This large budget industry has carried out considerable market research to find the most appealing features. The most relevant to the design and development of CAL programs include immediate feedback, reinforcement of correct response and user control. User control allows the users to take the most efficient path to content mastery by allowing them to organise the order of information presented. Relevance to the users is increased, resulting in improved motivation and self-confidence.

- Non-linear hypertext designed CAL programs allow students to discuss the programs with their peers. Although CAL was initially designed for individualised instruction, it was found that students who work together in small groups outperform students who work individually. This provides a major challenge for distance education.

Using the new multimedia authoring software, CAL programs became more amenable to continuous development than video, and depict complex concepts more precisely. However, the choice of animated graphics or video depends on detailed consideration of the specific educational objectives. Each mode has its merits and there is value in diversity of media format.

In the late 1990s compact disk read only memory (CD-ROM) drives which use optical disk technology became standard on personal computers to meet the explosive growth of storage demands of multimedia applications. This enabled the development of the current generation multimedia form of CAL described above by accommodating data files that take up huge amounts of storage space such as photographs, music, narration and even short digitised video clips, considerably enhancing previous limited multimedia capabilities.

Narration, for example, used to supplement other media such as text and graphics can greatly enhance understanding. The size of video files created the greatest challenge for multimedia developers but the development of video file compression software enabled video file size reductions of up to 95%. Access to CD-ROM quality multimedia CAL programs by video streaming direct from a web site cannot be adequately supported by the current narrow band Internet. However, the speed problem will soon be solved with the increasing availability of broadband Internet technology, discussed later. Until this is widely available at a cost affordable to most students, hybrid CD-ROM, in which content on the CD-ROM receives play commands through the web, will enable time dependent information to be readily updated at the web site, whilst retaining the multimedia quality of the CD-ROM.

The new generation of optical disk storage technology is the digital versatile disc (DVD-ROM). A double-sided dual-layered DVD-ROM disc can store 17 gigabytes. It is anticipated that within a few years personal computers will have a DVD-ROM drive as standard equipment and will enable the advantages of educational videos to be combined with the features of enhanced high quality multimedia CAL - including easy editing of the digital images through the multimedia authoring software.
Experimental course components

For off-campus students there are a variety of strategies to deliver the practical requirements of an engineering course. They include on-campus workshops, home experiment kits, video and CAL laboratory simulations and direct access to laboratory facilities via the Internet.

On-campus workshops

In Australian distance education, on-campus workshops are used to deliver the practical experiences essential for the development of a graduate engineer. They are usually scheduled for the inter-semester break or summer vacation period following study of the relevant unit but can be postponed to allow the practical requirements of several years of study to be completed in one visit. However the time delay between the student studying the theory off-campus and the practical work impairs its function of providing timely reinforcement of theories. The following strategies have been developed primarily to overcome this problem.

Home experiment kits

Home experiment kits are supplied with study packages although some home experiments simply require common household materials. They are designed to provide a practical demonstration of one or more concepts and have the advantage that they can be carried out at the time the student is studying the related theory and thus provide immediate reinforcement.

Video and CAL simulations

Video and CAL simulations of laboratory experiments have been developed for off-campus use. One advantage of video is that it can document special events and processes that students are unlikely to witness in any other way. One example is an experiment using production equipment at a major car plant to examine the effects of various input variables on metal deformation during a deep drawing process. The video shows the test process and significant physical results linking them to the test results presented in the study notes for the students to analyse. In a CAL example, the student performs the classic materials tensile test in an interactive computer simulation.

Direct Internet access to laboratory facilities

This concept was inspired by two web sites that became active in 1994 to demonstrate Internet based remote control of robots. One was developed by Ken Goldberg (Goldberg et al., 1994) of the University of Southern California and the other by Ken Taylor of the University of Western Australia (Trevelyan and Dalton, 1999). The first application of this principle to provide remote access to undergraduate laboratory facilities, was a fluids flow-over-a-weir experiment that relates the height of water over the top of the weir with volumetric flow rate (Florance et al. 1997). A second facility provided off-campus students Internet access to computer controlled machine tools (a lathe and milling machine) within a flexible manufacturing facility funded by the Australian Federal Government’s Committee for University Teaching and Staff Development, (Ferguson, 1997; Ferguson and Florance, 1999).

Communication and access to university services

Four of the five significant technological developments in distance education communications at the turn of the century are surprisingly old: the telephone and fax, the computer, and the Internet. The World Wide Web introduced in 1989 enabled more convenient use of the Internet. Supported by rapid advances in computers during the 1990s, the Internet now has the greatest effect on all levels of education including access to university services (e.g. library) and is facilitating the development of effective distance based engineering higher education. One of the most widely used and significant Internet application in distance education is computer conferencing, also called computer-mediated communication (CMC), which provides network-based, one-to-one and one-to-many interactive communication, supporting both independent and collaborative learning. The main communication medium is text, although it is anticipated that eventually voice and video will be become more widely available.

The use of technology to facilitate the delivery of professional attributes

The new focus on developing professional engineering attributes in undergraduate engineering courses was discussed in Chapter 9. Chapter 10 investigated teaching strategies to develop these professional attributes. However most of these strategies would be unworkable in a distance education course, without the more recent developments in the use of the new educational technologies. Hands on experiences and
activities to reinforce deep learning need to be available at the time of study as provided by the use of home experiment kits, video and CAL simulations and direct Internet links to laboratory equipment. The more immediate forms of communication enable exploration and clarification of concepts and re-inforcement by reflection. Deep learning in turn supports development of higher level competencies such as critical and creative thinking, analytical skills. These skills, together with information acquisition skills, are needed to support lifelong learning. A major problem in distance education is the use of group activities to effectively develop leadership and team skills and support innovation skills. The use of current communication technologies is restrictive but will be significantly improved when desktop broadband video conferencing becomes widely available in Australia.

A significant issue raised by a recent study (Lim and Lee, 2000) shows the level of basic information technology (IT) skills of Australian first year on-campus students to be ‘variable’. While the use of computers in industry is widespread, there are also many mature age distance education students who lack these skills. To achieve successful learning outcomes, there is an urgent need to provide these students with access to basic IT training early in their course.

Educational Technology in a Changing Education Environment

The global economical focus of higher education

The decline in Australian government funding during the 1990s forced universities to gain funding from non-government sources. International education became a major source of this funding. In the late 1990s university administrations looked to distance education as the means of providing “economy of scale”. The financial focus was more extreme in the US where a 1997 Coopers and Lybrand white paper (cited Farber, 1998) claimed that using packaged instructional software:

a mere 25 courses (subjects) would serve an estimated 80% of total undergraduate enrolment in core undergraduate courses. . . . Distributed learning involves only a small number of professors, but has the potential to reach a huge market of students.

Financially motivated, US State and federal politicians, university administrations and computer and communications companies rushed into “online” or “network” education. The anticipated gains were not realised (Noble, 1998). Rather than achieving economies of scale, many online courses were vastly under enrolled. As well as the major financial losses, the computer-based commercialisation of education created industrial unrest in the US and Canadian higher education systems. Academics at York University in Toronto went on strike for two months against administration initiatives to implement instructional technology.

There were failures. A study of the failing and surviving ‘virtual’ universities reveals that the failing providers were essentially instructor free and isolationist in approach, while survivors created and maintained the human touch of ‘attentiveness’ and intermediation. It is now recognised that high quality online teaching requires smaller staff student ratios than proximal teaching. Students must feel that they are part of a learning community and derive motivation to engage in the study material from the lecturer. For quality distance education courses the cost to the university per student is higher than for proximal teaching, particularly when the high set-up cost of developing course materials is taken into account. The US lesson was quickly assimilated globally. The UK Open University introduced a residential requirement in courses. In the US the focus on online education is returning to androgogy. Most now indicate an intention to employ combinations of delivery mechanisms eg: mixing proximal and online delivery, and are putting more academic staff into distance education delivery. In Australia there was renewed focus on the need to ensure interaction between staff and student and more financial realism. It seems the anticipated productivity gains are elusive.

Global competition

Arrangements to deliver Australian higher education in the (mainly) Asian market take the form of overseas students studying in Australia, off-campus (distance education - increasingly online) or ‘offshore campus’. The USA, France, Germany and the UK are historically the major suppliers to the various international higher education markets, however second only to Switzerland, international students in Australia now comprise the highest proportion of total higher education enrolments (approximately 11%) in the world.

The Asian economic downturn of the 1990s resulted in a loss of about 10% of Australia’s traditional higher education market in Asia. But Australia's economic links with Asia resulted in an exchange
Driven by the c
rate more in line with its neighbours, resulting in an equivalent market gain from other countries. Af-
fordability was further improved through offshore campus arrangements, enabling students to study part-
or their entire course in their own countries. Australian universities are also more geared to efficient arti-
culation arrangements enabling students to study the first year or two of their degree locally. Working
against these factors is the cost to obtain an Australian student entry visa compared with that for other
main host nations and for students from China, India and Vietnam the time to get an Australian visa is
considerable. The global nature of distance education has resulted in international competition and the
substantial Australian expertise in flexible distance based higher education has provided competitive ad-
vantage. Asia continues to provide the largest overseas higher education market for Australia but there
are also moves to secure markets further afield. For example, the APESMA MBA is not only delivered
in a number of Asian countries, but is now expanding to several other countries throughout the world.

Changes in Australian tertiary education
The last few decades of the 20th Century saw the end of free higher education with students now re-
quired to contribute substantially to the cost, while the massive expansion in student numbers in the uni-
versity sector has lead to a wider range of student abilities. This resulted in a shortage of academic staff,
overcrowding of students and pressure for new buildings. In late 1989 six higher education providers
were designated as Distance Education Centres (DECs) with special funding arrangements but the expec-
tation of reduced staff requirements was not achieved and special funding was removed in 1993. Throug-
Throughout the 1990s corporatisation of the Australian university sector and the adoption of the notion
of student as client was driven by increased government demands for financial accountability, the need
to commercialise activities for financial sustainability and pressure for full fee paying places alongside
government subsidised places in undergraduate courses. Instead most universities focused on full fee
paying coursework higher degrees and non-award courses usually taken by mature students combining
study with full-time employment where tax deductions would make the course more affordable.5 Flexi-
bility of distance education provides substantial advantages. From just six DECs a decade ago now vir-
tually all universities have some involvement.

Continuing Professional Development
Internationally this is the fastest developing education market and is principally targeted by corporate
and private institutions of higher education world-wide, but particularly in the USA where employers are
more focused on the competitive advantages accruing from a highly skilled and flexible workforce.
Many students can substantially offset their study costs by employer sponsored tuition subsidies and tax
breaks.

Concerns about large-scale influx into the Australian continuing professional education market re-
sulting from the explosion of US ‘global’ private and corporate universities seem unfounded (Cunning-
ham et al. 2000). Internationally, Australian providers have a competitive edge through leadership in dis-
tance and distributed education, focus on work-readiness and professional attributes, and cost effective
and agile response to client needs.

Australian Distance Education - the Future.
Australia's market share of the international distance education market is increasing rapidly against a
highly competitive field with an increasing proportion studying off-campus or at an offshore campus. Much
is due to well-established expertise in distance education and use of educational technologies, ex-
perience with part-time higher education students, established local partnerships and alliances, and a stu-
dent centred customer focus. Good market research has enabled Australian providers adapt to the rich
variety of cultures and economic conditions that demand different approaches to delivery, including dif-
ferent forms and levels of support. In spite of the problems of poorly mediated online education in the
US there is an increasing demand for (well-supported) online delivery and there is also an increasing
awareness of the need for internationalisation of content.

Quality assurance issues are becoming critical in the international market place as fiscally moti-
vated global competition along with the massification of higher education places a risk on the quality of
educational process and continuance of educational standards. Currently each Australian university in-
ternally self-accredits its degree programs but internationally many countries, including the UK, USA,
New Zealand and many European countries, are establishing rigorous national accreditation agencies.
Driven by the concern to protect the Australian higher education export industry, the Australian Univer-
sities Quality Agency will commence early in 2001. Quality assurance of educational standards is particularly critical for professions such as engineering. In Australia the IEAust provides professional accreditation of engineering courses with international standing provided through international agreements to mutually recognise the substantial equivalence of accredited academic programs. (Washington Accord, see Chapter 5, p. 35.)

Nationally the technologies of distance education are also set to substantially change the face of on-campus teaching. Distance education is increasingly used in Australian secondary education to overcome specialist academic skill shortages in single subjects. This develops in these students some of the self-discipline, maturity and technical competency needed for off-campus study. This factor, combined with the increasing need for on-campus students to work part-time to provide their only or major source of income (Cook and Couchi, 2000), and the greater range of abilities of our students, indicates the appropriateness of adopting some of the flexibility offered by distance education technologies in on-campus teaching. Availability of computer-based communications can also provide opportunities for increased peer support and interaction. As almost every Australian university now has facilities and expertise in distance education, their adoption to meet on-campus student needs is inevitable. In effect this is moving along the path towards providing distributed learning for traditional students and blurring the distinction between off and on-campus students.

Distance education that is well supported technically and with good lecturer interaction is now recognised to be more expensive for the providing institution than proximal teaching, but is more educationally efficient and facilitates continuing employment. This provides economic advantages for student and nation and is crucial for the viability of continuous professional development. The continuing move towards full fee paying courses in Australia could result in pricing differentials between on and off-campus delivery, as in the US. Recognition in the US of the need to ensure good interaction between lecturer and student led to the use of tele-conferencing combined with computer-mediated communication as a favoured form of distance education delivery. This form of delivery is more problematic in science and engineering where mathematical, graphical, and diagrammatic concepts need to be explored by synchronous group discussion. Desktop video conferencing using broadband web access to enable group project work as well as small group technical tutorials for off-campus students should provide a solution.

According to Bill Gates of Microsoft, broadband access in Australia is two years behind Europe and North America where its capabilities are already being applied both in education and industry. However, it is uncertain whether this will eventually fully support the development of the ideal engineering attributes without a continuing need to blend in aspects of on-campus delivery. In the past the special demands of distance based engineering education led to significant development of a wide range of enabling technologies. The attribute focus has now generated a new set of challenges.

Notes to Chapter 11
1. Examples of the use of media technology given in this section are from Deakin University.
2. The term “course” in North America is equivalent to a “subject” in Australia.
3. Based on a different definition of ‘distributed learning’ than given on page 98.
4. In the process new fully online and ‘hollow’ providers were created. Confusingly both are known as ‘virtual’ universities. The ‘hollow’ university is more established and is essentially a course broker for a number of distance education providers. Hollow universities now increasingly offer online courses.
5. There is an equity issue here. Those in lower income groups may no longer be able to afford the continuing education increasingly required to maintain employability.
Chapter 12  
Personal Development and the Engineering Associations  
By Brian E Lloyd  
Introduction  
This chapter reviews educational needs and provisions for professional people in engineering. Successful employing organisations recognise that personal development of employees, linking education and practice, raises productivity. Training courses and postgraduate education leading to qualifications in advanced engineering or new technology or business competencies, benefit both the organisation and participating individuals. The ultimate measure of efficacy is found in improved personal performance and in the vocational satisfaction achieved by the participants.

This chapter emphasises continuing professional development (CPD) in the horizontal dimension of career progression for Professional Engineers. Specific technical competencies for engineers are acquired in the undergraduate degree course that provides admission to professional practice. Effective subsequent practice implies successful exercise of general professional competencies in the wider context of making a living in a changing world. Consideration of three general competencies in relation to the contradictions and confusions of the new professional paradigm discussed in Chapter 15 provides a context for professional development:

1. Knowing what is going on: keeping up with engineering and its context. The effective person understands the profession in society, the role of the individual in it, and:
   - is a member of professional bodies, participates in functions and leadership, and
   - keeps up through courses, conferences, and reading engineering publications.
2. Having the tools needed for effective operation: maintaining and extending technical competence.
   Registration on NPER denotes current competency in particular fields.
3. Having the ability to operate effectively: independent practitioners, and salaried and contingent employees in flat organisations, receive little guidance, operate in professional autonomy and exercise leadership without organisational authority, and are responsible for their own opportunities and CPD, especially in business and leadership competencies.

The new professional paradigm has brought major change in the competencies crucial to effectiveness, and engineers require a long-term commitment to maintaining and refreshing expertise in challenging managerial environments. Contingent employees require expertise in challenging technical environments. All require life-long commitment to CPD in mixtures of technical and managerial knowledge and skills.

The chapter also includes a discussion of education for occupational transfer from paraprofessional to Engineering Technologist, and Engineering Technologist to Professional Engineer. Such education is in the vertical dimension of career progression discussed in Chapter 6.

The IEAust policy on CPD, developed in the late 1980s, is related to ethical obligations to maintain and extend competence in areas of expertise professed in practice. It requires a rolling average of 150 weighted hours over three years, embracing postgraduate studies in engineering technology and management, professional society activities, conferences, papers, and the like. Chartered and Registered Engineers are expected to maintain a record of CPD, subject to random audit. Many initiatives increased access to professional development, particularly through distance education, and through availability of postgraduate studies for master and doctoral degrees. The association of employees, APESMA, responded first and most effectively to the growing need for professional development, and made provision for access to a variety of forms of continuing education, including the most successful MBA program in Australia. The IEAust also responded with postgraduate offerings in engineering.

Engineering Careers and Employment  
Definition of responsibility levels in the public sector provides insights into the attributes of engineers as they gain experience. Definitions were developed in 1961 and updated in 1990, and the principles remain valid even though the hierarchical approaches in organisations have undergone change. The Australian Public Service (APS) Position Classification Standards for engineers Classes 1 to 5 were based upon principles developed in the private sector in the UK and Canada, reflected the universal nature of engineering organisations, and established common ground for Australian organisations in the public and
private sectors. Updating the PCS for Engineers Classes 1 to 5 in the APS was effected in a detailed study that covered federal and state public organisations and large private engineering-based companies. The aim was to engender creative performance while eliminating bureaucratic constraints. Definitions are summarised in Table 12-1. During the 1990s some modifications were made to classification structures, but the principles did not change.

### Table 12-1
**Typical Professional Engineering Responsibility Levels**

| Class 1 Graduate Engineer: | Experiential formation under decreasing supervision; normal professional engineering duties with minimum supervision.* |
| Class 2 Experienced Engineer: | Undertakes more novel, complex or critical professional engineering duties under decreasing supervision and normal professional engineering duties without supervision.* |
| Class 3 Senior Engineer: | Applies mature engineering knowledge and judgement and performs professional engineering duties with professional autonomy. May supervise engineers and others. |
| Class 4 Managing or Specialist or Senior Practitioner Engineer: | Professional engineering duties requiring extensive experience, originality and judgement, in managing, or as a senior engineer practitioner or specialist engineer. |
| Class 5 Managing or Specialist Engineer, Senior Engineer Practitioner: | Undertakes professional engineering duties requiring comprehensive knowledge of policies and decisions on significant functions, in managing a larger unit or coordinating the work of smaller units, or undertaking senior practitioner or specialist activities. |

**Executive Engineer (Several responsibility levels)**

Practice as a managing engineer, or specialist or practitioner above Class 5.

* Normal professional engineering duties are in established engineering procedures, methods and standards, and exclude novel, more complex or critical work.

For engineers, initial work experience quickly extends competencies through induction to work and cultivation of people skills. Responsibility increases rapidly until the engineer reaches the equivalent of Class 3, when a state of *professional autonomy* is reached: relative independence of decisions and methods of approach in the performance of more novel, complex or critical professional engineering duties, within a managerial framework of coordination of effort, objectives, economy and resource allocation. In the past, many careers progressed to engineering management in Class 4 or 5, but in the new era many more lifetime careers are likely to be in the technical practice or project work, especially in contingent employment. For those who progress to senior levels as Specialist and Executive Engineers, the PCS Review described two role dimensions: the essential *Professional Engineering Dimension* requiring occupation-specific understanding and judgement, and the *Administrative Dimension* concerned with essential non-occupation-specific management and executive skills. In the new world, conditions and attitudes prevalent in the private sector are more relevant to most engineers.

High job mobility requires a continuous drive for high performance. In companies employing large numbers of engineers, approaches to remuneration are related to performance in responsibility levels resembling those of the APS. In 1988 APEA commissioned a study on *Performance Pay for Professional Engineers* to provide guidelines for appraisal of performance above Experienced Engineer or Initial Chartered status. The report pointed out that each factor for appraisal must have regard to the normal expectation of performance in relation to the responsibility level and role of the engineer. The factors defined were: effectiveness, competence, leadership and adaptability, and such factors remain valid for CPD to reinforce both corporate goals and individual professional goals. Changes in the 1990s mean that an increasing number engineers are in contingent employment, shown in APESMA Surveys as rising from 4 per cent in the 1990 to 10 per cent in 2000. For such engineers, there must be greater self-reliance for CPD as an essential prerequisite for expertise and adequate remuneration.

**APESMA Management Initiatives**

At the end of the 1980s the leaders of APESMA addressed the self-help orientation of private industry engineers through provision of distance education in management. The initiative arose from the organisation responsible for the industrial relations of employees, rather than from a broader view that might have been expected from IEAust. In 1987 the Association initiated a distance education Postgraduate Diploma in Management comprising 6 study units, each one-third larger than the 'standard credit point' because of longer semesters. Deakin University was contracted to organise examinations and publish Distance Education study materials prepared by expert authors engaged by the Association. The Diploma was accredited in Victoria and nationally registered. It was an immediate success. The first intake in 1989 was 750. Enrolments in 1992 exceeded 2400, including 10 per cent from overseas.

In 1991 the program was extended with a further 6 units to form the MBA (Technology Manage-
Field research initiated by APESMA in several engineering organisations in 1992 identified needs at all levels for CPD in addressing the broader needs in technology and management for leading and managing change. The project had significant flow-ons, including an additional incentive for IEAust to revise the criteria for recognition as a Chartered Professional Engineer, and influencing the APESMA/Deakin MBA program offerings and the Deakin/EEA master degrees discussed below. In 2000 APESMA, through its subsidiary Professional Development Europe Ltd (PDE), became the first Australian institution to be accredited through the UK Open University to deliver distance education for an MBA and an MBA (Technology Management). The accreditation process involved review of all aspects of the study program as a postgraduate level award consistent in standard with degree-awarding bodies in the UK. To meet the demanding UK quality assurance regime, the APESMA company began working with leading academic specialists in major Business Schools in the UK to customise the study material to reflect the local market. The program was launched in mid-2000.

To provide for other immediate skill needs, in 1990 the Association launched a series of short courses, the range of which was extended throughout the decade. In 1996 a Certificate in Frontline Management and a Graduate Certificate in Management were introduced. With the broadening of the membership base of APESMA to include scientists and other technology-based professionals, in the first decade of operations these professional development offerings became accessible to a very wide market in which engineers made up 77 per cent. In breaking new ground in providing these benefits for members, the vital factor of success was relevance to professional development and career progression.

IEAust CPD Initiatives

The IEAust was invited to participate in the APESMA diploma when it was being mounted, but instead unsuccessfully promoted a program from a university in competition with APESMA. In 1990 IEAust set up Engineering Education Australia Pty Ltd (EEA), to facilitate access to continuing professional education. An innovative approach was taken in arrangements with a number of universities for access to a range of distance education study units, for inclusion in individualised programs for a Graduate Diploma of Engineering (Professional Development), accredited in Victoria and registered nationally. To augment the university offerings, EEA engaged experts to develop a series of additional postgraduate study units in specialised engineering fields and in project management.

A further initiative was development of a Diploma of Engineering Technology to provide an articulated pathway for engineering para-professionals to qualify as engineering technologists. A number of Level 2 and 3 units in technology and management were developed, based on TAFE national curricula, and EEA became a registered TAFE provider. Development of distance education study resources was funded by IEAust, the NSW Education and Training Foundation and the Victorian Education Foundation. In 1994 EEA entered a partnership with the School of Engineering and Technology at Deakin University, and subsequently with several other universities.

The EEA/Deakin partnership resulted in a BTech(Engineering & Management) as an engineering technologist qualification, and an M Tech(Engineering & Management) as a professional engineering qualification, each accredited by IEAust as individualised programs for mature age applicants having significant work experience. The BTech(E&M) was more attractive than the EEA Diploma, which drew few students. As a post-BTech program, the M Tech(E&M) was required by University regulations to be 16 credit points, and the award of a master degree was justified by significant postgraduate content. With up to half the content sourced from Deakin University, the remaining units could come from the EEA list, and advanced standing was available for studies beyond the 3-year qualification. The first graduates emerged in 1996 and 1997. The features of the programs were:
• **BTech (Engineering & Management):** to articulate from a variety of qualifications providing credit for prior learning, for example: a 2-year TAFE qualification and experience plus 9 units including mathematics for technologists. The program included a limited number of the EEA Level 2 and 3 units.

• **MTech (Engineering & Management):** to articulate from a variety of 3-year qualifications. A person with a 3-year qualification could complete the degree with:
  - 2 points at Level 4, for study and competency assessment as a Technologist Stage 2.
  - 2 points for engineering mathematics, with possible credit if prior studies.
  - 6 to 7 points in engineering applications, not less than 2 postgraduate level, with provision for inclusion of limited bridging studies at Level 3 and 4.
  - 3 to 4 points in management, not less than 2 at postgraduate level.
  - 2 postgraduate points, for studies and competency assessment as a PE Stage 1.

By the end of 1999 Deakin University policies had shifted and alternative strategies were needed to replace MTech(E&M). By that time EEA offerings were augmented with distance education BE and BTech programs offered by the University of Southern Queensland. Deakin University was considering a flexible distance education BE program through EEA to replace the MTech, but at the time of writing funding restrictions were causing the outlook for customised university articulated pathways to be pessimistic.

**Deakin/EEA Postgraduate Distance Education Programs**
The EEA/Deakin partnership produced other distance education offerings as individualised postgraduate programs for mature age applicants with significant work experience:

• **ME:** 12 point for engineers - 2 for a project and 10 for studies, up to 4 in management.

• **MTech:** 8 points for engineers, up to 4 in management.

• **Graduate Diploma of Engineering:** 8 points for engineers.

• **Graduate Diploma of Technology:** 8 points for technologists.

Participation in the EEA programs built up to a steady state of about 150 in the BTech(E&M), 40 in the MTech(E&M) and 200 in the ME and MTech.

**Other EEA Distance Education Coursework Programs**
The University of Southern Queensland offers two 12 credit point postgraduate coursework programs by distance education, of relevance to engineers and technologists and available (not exclusively) through EEA. Candidates may select up to 6 postgraduate non-USQ units from the EEA list. The MBA is designed for candidates experienced in business or government, and provides a generalist course or specialisation in areas that include project management, environmental management, occupational health & safety, and information systems. The Master of Engineering Technology (MET) is designed for engineers, scientists and other technology professionals, with majors in agricultural, computer systems, electrical and electronic, environmental, instrumentation and control, mechatronic, and municipal engineering. The MET programs provide for variable blends of engineering and management selected by candidates:

• 4 points: undergraduate or Level 4 or 5, in a specialist area.

• 3 points: at Level 4 or 5, in the specialist area.

• 1 point: Engineering & Surveying Research Methodology (Level 5).

• 4 points: Project & Dissertation.

The EEA offerings also include courses in various specialisms from:

• U of Southern Queensland: BTech, BE.

• U of New South Wales: MEngSc (12 points from 8 study units).

• U of Technology Sydney: Master of Engineering Management, and Master of Environmental Engineering Management (10 points).

• RMIT University: Master of Business in Information Innovation (12 points).

• Monash University, Gippsland: single units.
Professional Doctorates

Deakin D'Tech Program

Three professional doctoral programs in advanced professional practice are offered for engineers through EEA and APESMA, to be studied anywhere in Australia and overseas.

Deakin University introduced the Doctor of Technology program in 1995 in the Faculty of Science and Technology. The first candidates commenced in 1996 and the first graduated in 1999. The majority were in engineering, and some were overseas. The role of EEA is to introduce the program but not as an exclusive arrangement. A principal aim of the doctorate, which stands beside the traditional research-based PhD, is to enhance leadership of innovation in professional practice. The DTech program requires accumulation of 24 credit points, the equivalent of three years full-time academic work. Individualised programs are specified by agreement between the candidate and the University, comprising 8 credit points in advanced studies, including a mandatory Orientation Unit, and 16 credit points demonstrating advanced professional work and high expertise, culminating in presentation of an exegesis. Candidates able to demonstrate high professional standing and academic achievement at postgraduate level may have such achievements included in the doctoral program to a maximum of seven credit points. The doctoral work is expected to demonstrate leadership and innovation, as well as aspects of entrepreneurship to achieve professional and commercial outcomes.

The Exegesis comprises a written text addressing critical issues, analyses and conclusions that may be supported by other documentation or artefacts. The DTech is examined on the basis of demonstrated expertise, innovation, enterprise achievement or research representing advances in professional practice. The overriding criterion is demonstration of scholarship of application. The beneficial outcome for candidates is expected to be significant enhancement of capacity for leadership and creativity in professional practice in a holistic sense.

APESMA/CSU DBA Program

In 1999 an arrangement between APESMA and Charles Sturt University brought a joint Doctor of Business Administration (DBA) end-on to the MBA (Technology Management). The DBA is accessed through APESMA for applicants with relevant management experience and credit level performance, to provide opportunities to refine and extend business education at an advanced level. The doctorate provides the framework to expand knowledge, and the opportunity to undertake a business or management project. Industry and academic specialists were engaged to prepare study guides, readings, activities and assignments. Admission requirements include a minimum 5 years experience in managing programs and developing or evaluating significant policies, programs or initiatives, being the recognised authority in a complex specialised work area, and develop and applying new principles and technology, or providing professional or consultancy services with recognised standing across or outside their business institution. In addition, the applicant must be working in or have access to business, where the practical requirements can be undertaken. The program includes 6 study units and is equivalent to 14 credit points following an MBA. The minimum duration is 2 years full-time or 4 part-time, requiring 12 to 16 hours per week over 20-week semesters. All study units must be completed before the dissertation, which is weighted as one year full-time.

USQ DBA Program

In 1999 an arrangement with the University of Southern Queensland enabled EEA to promote a new DBA, but not exclusively, end-on to the USQ MBA program or an equivalent qualification. Specialist areas include project management, information systems, marketing, human resource management and international business. Applicants normally have a minimum of 5 years relevant experience including 2 years in management, and the DBA program comprises: 4 points: from one of the MBA specialist areas, 1 point for Research Methodology, completed before the Dissertation, 3 points for Contemporary Issues in Business Administration, and 4 points for a Dissertation. Up to 6 credit points of advanced standing may be allowed for non-USQ units of doctoral level.

Conclusions

The period 1980 to 2000 could well be called the era of CPD. The IEAust defined a policy framework in relation to the ethical obligations. Many initiatives contributed to a major enlargement and enhancement of CPD opportunities, particularly through a resurgence of the old strategy of distance education, and availability of postgraduate studies for diplomas, master degrees and professional doctorates. Both
IEAust and APESMA forged strong linkages with Universities and made provisions for a variety of CPD for mature-age professionals. The lead was taken by APESMA in management education, while IEAust fostered postgraduate studies in engineering and articulated education. These educational provisions now stand beside the traditional on-campus provisions of research and coursework postgraduate master degree programs described in Chapter 7, and the PhD degree by research. The number of engineers participating in MBA and related programs is of a similar order to those enrolled in postgraduate engineering programs.

Distance Education studies fulfil a large scale need in management studies rather than in advanced engineering: the APESMA/Deakin distance education MBA(Technology Management) far outstrips any other single program undertaken by engineers. In rejecting the initial offer to participate in this outstandingly successful program, the short-sightedness of the decision-makers in IEAust at the time probably reflected prejudice against 'the union' as much as a lack of contact with current trends and needs in engineering employment.

The many engineers who study on and off-campus engineering coursework master degrees at various universities display enthusiasm for deepening their engineering expertise. Such engineers follow their commitment to enhanced professional engineering practice as their dominant career choice. The Deakin/EEA distance education master degrees provide individualised opportunities blended with management studies. While these programs are large by comparison with postgraduate programs offered on-campus by most engineering schools, participation in them is an order of magnitude smaller than in the APESMA/Deakin MBA.

The many engineers undertaking the APESMA/Deakin MBA respond to the opportunity for studies in business and engineering management. The USQ Distance Education MBA provides similar opportunities. Engineers who undertake these studies to enhance their performance and career prospects as engineers, see the MBA as enhancing their career prospects in competition with other occupational groups seeking to displace engineers in executive positions related to engineering. It is likely that many other engineers who take the MBA see it as a means of escaping from engineering into a less intellectually demanding and more rewarding career in management. Such a motivation might also arise from a perception, and the reality, of difficulty in keeping up with advances in technology in competition with the high level of education in modern engineering technology exhibited by recent graduates.

Successful organisations recognise that personal development of professional employees enhances enterprise productivity. Courses leading to postgraduate qualifications in advanced engineering technology, or in new technology, or to enhance managerial and business competencies, benefit both the organisation and participating individuals. The ultimate test for the efficacy of postgraduate study (or in-house training or continuing development of any kind) is found in the enhancement of performance of the participants and, just as importantly, in the increased vocational satisfaction achieved by the individuals.

It is evident that the response of engineers to the variety of CPD on offer is strongly associated with the new professional paradigm of engineering discussed in Chapter 15.

Notes to Chapter 12

1 The Review Team comprised engineers: Frank Martinelli (Leader), John Stradling and Alf McMicken from the APS, Brian Lloyd representing APEA, and a member of the Professional Officers Association (POA).
3 Two major areas of engineering employment, APS and Telstra, revised position classification structures and substituted the generic 'professional' in place of 'engineer', thus opening positions to non-engineer professionals and eliminating the occupational identity of engineers.
5 Skills for the Future, a report on occupational field research in several large Australian engineering based organisations, for identification of future 'skill enhancement' needs, or CPD.
Chapter 13
International Comparisons
By Brian E Lloyd

Introduction
This chapter reviews aspects of engineering in the United Kingdom and United States as primary exemplars of the English-speaking tradition from which Australian engineering was derived. There are contrasts between the accreditation and formation processes in UK and USA, and some representative samples from each of engineering and technology courses provide broad benchmarking of educational and professional formation for Australia. Minor insights into the para-professional level also are considered.

The engineering workforces in the UK and US are much larger than in Australia, and they operate in much more dense industrial manufacturing and infrastructure environments. Regulatory functions in engineering are somewhat more developed than in Australia for the three categories of professional engineer, engineering technologist and para-professional. In the UK accreditation is embedded in the total system of formation leading to registration. In the US accreditation is conducted by a body formed by the various professional engineering bodies, but disconnected from registration. As in Australia, accreditation of education defines the three work-force categories.

Engineering Council in the UK
Engineering education in the UK after World War 2 evolved through several stages. In the 1950s the Colleges of Advanced Technology and the Diploma of Technology of the National Council for Technological Awards were precursors of new universities in the 1960s. Polytechnics also were created to conduct courses for degrees of the Council for National Academic Awards (CNAA). The National Certificate system was placed under the Technician Education Council, and that route to Chartered Engineer ceased.

The Council of Engineering Institutions (CEI) was founded by Royal Charter in 1965 to set a common BSc(Eng) standard and an examination to replace the variety of examinations of the institutions, and to create a Register for Chartered Engineers, 'Technician Engineers' and Engineering Technicians. Tensions with the engineering institutions brought the more independent Engineering Council under a new Charter in 1981. In 1984 the EC defined the top categories in the engineering work-force in Standards and Routes to Registration (SARTOR).

In 1988 the designation 'Technician Engineer' was changed to 'Incorporated Engineer', the benchmark qualification being the Higher National Diploma or Certificate. New admission standards for professional engineers were set at 3-year BEng Honours, or 4-year MEng programs. Under the newly formed Business and Technician Education Council (BTEC), the benchmark qualification for Engineering Technician was the National Diploma or Certificate, 2 years full or part-time from GCE O level. The benchmark for Incorporated Engineers became the BTEC Higher National Diploma or Certificate. Those who did not achieve honours in the BEng, or who completed a relevant BSc or equivalent, qualified for 'Incorporated Engineer'.

The revised SARTOR in 1990 described 'engineering' as an interdisciplinary and interdependent team, many of whom claim to be 'engineers' but who possessed a diverse range of qualifications entitling them to be registered as CEng, IEng or EngTech, together with science and other qualifications. Table 13-1 sets out the functional features for CEng and IEng, and the Council defined 'Engineer' to embrace both as persons acquiring and using scientific, technical and other pertinent knowledge and skills to create, operate or maintain safe, efficient systems, structures, machines, plant, processes or devices of practical and economic value. Confusion about 'engineer' thus was enshrined.

In 1997 a new SARTOR upgraded the educational bases for CEng or IEng as specified in terms of the UK-based qualification benchmarks illustrated in Figure 13-1. The levels for CEng and IEng were expressed by the European formula of '4U' and '3U' respectively, where 'U' is the outcome of one traditional year in a university. In terms of UK qualifications:

- Chartered Engineer = 4U, as a 4-year MEng, or = 3-year BEngHons + 1 year FT equivalent learning.
- Incorporated Engineer: = 3U, as in 3-year BEng/BSc, or = 2-year HND + 1 year FT equivalent learning.
A course is deemed to meet the educational requirements for CEng if graduates achieve the attributes set out in Table 13-2. The MEng includes increased depth in engineering and breadth of non-technical topics, and greater industrial involvement than the BEng. As degree-level professionals, Incorporated Engineers require a balance of technological, management and personal skills to prepare for early managerial and leadership responsibility, rather than as inferior versions of programs for potential Chartered Engineers. The IEng degree has less focus on analysis and in-depth study when compared with the CEng degrees. The thus EC promotes two mainstream degree programs for the differing requirements of potential CEng and IEng candidates. Phased implementation began in 1999, to be fully in place by 2002.
To ensure the quality of students admitted to accredited degree courses, the EC imposes a controversial ‘filter’ in the form of a minimum entry standard for 80 per cent of the entry cohort. For CEng courses the requirement is three GCE A-levels (or equivalent) including mathematics and physics. For admission to an MEng, 24 A-level points (or equivalent) are required, and for an accredited BEng (Hons), 18 points. It is recognised that this will restrict recruitment. For IEng courses, 80 per cent of the entry cohort need a minimum of 10 A-level points, or equivalent, in appropriate subjects. Students with weaker A-level performance may proceed via an HND followed by an appropriate Matching Section to IEng registration.4

**Occupational Standards**

The Areas of Competence defined for CEng and IEng in SARTOR (1997) are summarised in Table 13-3. Occupational Standards are defined under the aegis of the Occupational Standards Council, and approximately equate to the National Competency Standards in Australia. In the UK the Standards are derived from jobs and functions and described in terms elements of competence, performance criteria and evidence indicators. The methodology begins with a key purpose statement from which a sub-division of roles emerge. Knowledge and understanding are specified separately but are embedded in the Standards. Four sets of standards for engineering have been developed: for Engineering Services, Engineering Manufacture, and Extraction and Processing. Development of Standards is an ongoing process.

<table>
<thead>
<tr>
<th>Chartered Engineers</th>
<th>Incorporated Engineers</th>
</tr>
</thead>
<tbody>
<tr>
<td>- The educational base for Chartered Engineer.</td>
<td>- The educational base for Incorporated Engineer.</td>
</tr>
<tr>
<td>- Specialist knowledge and skill in a field of engineering and existing &amp; new technologies.</td>
<td>- Specialist knowledge and skill in field for application of existing technology and management.</td>
</tr>
<tr>
<td>- Application of theoretical and practical methods to solution of challenging engineering problems.</td>
<td>- Application of theoretical and practical methods to solution of technical and management problems.</td>
</tr>
<tr>
<td>- Leadership in a technical function in research, design, development, manufacture, construction, commissioning, operation, or maintenance.</td>
<td>- Leadership in a technical function in research, design, development, manufacture, construction, commissioning, operation, or maintenance.</td>
</tr>
<tr>
<td>- Leadership and personal skills in management, and clear exposition of complex issues.</td>
<td>- Leadership and personal skills in management, and clear exposition of technical and managerial issues.</td>
</tr>
</tbody>
</table>

**EC Examination and Mature Candidates**

The first CEI examination in 1967 comprised 6 papers in each of Parts 1 and 2. The same format remains, with the addition of a Report and adjustment of the standard to current levels. Part 1 comprises Mathematics, Engineering Materials, Engineering Science and Engineering Perspectives and Skills, and two from Mechanical and Structural Engineering, Thermodynamic, Fluid and Process Engineering, Electrical and Electronic Engineering and Software, and Information Systems Engineering. Part 2 for 2001 Examination is to be beyond the British honours bachelor degree standard, and comprise:

A. Five technical papers in an engineering discipline. Candidates are allowed up to three attempts in three successive examinations to accumulate the total of five subject passes. See Table 13-4.

B. Engineer in Society: covering communication for professional engineers, impact of technology on society, organisation of engineering activities from design to marketing and from manager to work force.

C. A report on an engineering project undertaken. The report may be submitted at any time within four years of the first entry to Part 2(A).

Candidates are advised to do a formal course including laboratory work, but the Council will consider applicants who study by distance learning or other means.

Mature Candidate for Registration, lacking academic qualifications currently acceptable must be at least 35 years old and have experience in positions of responsibility relevant to engineering over at least 15 years for CEng or IEng, or 12 years for EngTech. The process requires demonstration of knowledge and skill comparable to contemporaries in the section of the Register to which admission is sought. Normally the test is based on a written report and an oral examination. For CEng a 10,000 word report is required, and 3,000 to 5,000 words for IEng and EngTech, each demonstrating an ordered and critical exposition of related engineering practice. Alternatively it may be a single speciality paper based on a design project or original work. Applications are assessed by panels on behalf of the Sponsoring Institutions and the EC, and the interview confirms the range and depth of knowledge and understanding.
The Registers
The total registrants in 1998 on the three-category Register of the Council had stabilised at about 287,000, including 264,000 in the categories of CEng, IEng and EngTech, and 23,000 at graduate level. There were 230,000 resident in the UK, and the total included 5000 women. Assuming that 10 per cent of Chartered Engineer registrants were retired, the remaining 160,000 UK resident professional engineers on the Register represent about 40 per cent of the estimated professional engineering labour force.\(^5\) The number of UK resident registrants in the equivalent engineering technologist category was some 54,000 and engineering technicians about 16,000, in both cases including retirees.

Accreditation in the USA

**Accreditation Board for Engineering and Technology**

The Accreditation Board for Engineering and Technology (ABET) began in the United States in 1932 as the Engineers Council for Professional Development, to promote the status and quality of engineering. From 1980 ABET was concerned with accreditation. Expanded in 1997 to include applied science programs, ABET accredits some 2,300 engineering, engineering technology and engineering-related programs at over 500 colleges and universities. As a federation of 28 professional and technical societies, professionals from industry and education form the Board of Directors and three Commissions.

Accreditation of professional engineering courses is conducted by the Engineering Accreditation Commission (EAC). Accreditation of programs in engineering technology commenced in 1944, now under the Technology Accreditation Commission (TAC). In 1976 other programs came under the Related Accreditation Commission. This chapter is concerned with the EAC and the TAC. ABET is recognised by the US Department of Education, the National Council of Examiners for Engineering and Surveying, nearly all relevant boards of licensure and certification, the professional engineering societies, employers, and the educational institutions.

<table>
<thead>
<tr>
<th>Table 13-4</th>
<th>Engineering Council Examination Part</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2(A): Subjects</strong></td>
<td></td>
</tr>
<tr>
<td>Applied Thermodynamics</td>
<td>Electrical Machines and Drives</td>
</tr>
<tr>
<td>Analysis &amp; Design of Manuf Systems</td>
<td>Electrical Power Systems</td>
</tr>
<tr>
<td>Applied Thermodynamics</td>
<td>Electronic Systems Engineering</td>
</tr>
<tr>
<td>Built Environment</td>
<td>Engineering Surveying</td>
</tr>
<tr>
<td>Building Services Eng Design</td>
<td>Fields and Circuits</td>
</tr>
<tr>
<td>Chem Thermo, Kinetics &amp; Reactor D'n</td>
<td>Fluid Mechanics</td>
</tr>
<tr>
<td>Communication Systems Eng</td>
<td>Fuel and Energy</td>
</tr>
<tr>
<td>Computer Systems Engineering</td>
<td>Geotechnical Engineering</td>
</tr>
<tr>
<td>Control Systems Engineering</td>
<td>Heat and Mass Transfer</td>
</tr>
<tr>
<td>Design &amp; Operation of Marine Vehicles</td>
<td>Information Systems Eng</td>
</tr>
<tr>
<td>Dynamics of Mechanical Systems</td>
<td></td>
</tr>
</tbody>
</table>

Criteria for evaluation of courses address quality and management of students, curricula, staff and facilities, and set out the attributes to be demonstrated by graduates, as summarised in Table 13-5.\(^6\) The 4-year
program for professional engineers must include one year college level mathematics and basic sciences appropriate to the discipline, 1.5 years in engineering sciences and engineering design, and general education that complements the technical content of the curriculum and is consistent with the program and institutional objectives. The third requirement previously was stated as 0.5 years of humanities and social sciences, specifically excluding management related-material, but the new less specific requirements permit more engineering-related material.

Each engineering program is required to satisfy additional defined Program Criteria in one of the engineering specialisms listed in Table 13-6. Professional engineering programs are required to prepare graduates for engineering practice through a design experience incorporating standards and realistic constraints that include most of economic, environmental, sustainability, manufacturability, ethical, health and safety, and social and political issues.

### Table 13-6
Specialisms for which ABET Special Program Criteria are Defined

<table>
<thead>
<tr>
<th>Specialism</th>
<th>Engineering Management</th>
<th>Metallurgical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aerospace</td>
<td>Engineering Mechanics</td>
<td>Mining</td>
</tr>
<tr>
<td>Agricultural</td>
<td>Environmental, Sanitary</td>
<td>Naval Architecture and Marine</td>
</tr>
<tr>
<td>Architectural</td>
<td>Geological</td>
<td>Nuclear</td>
</tr>
<tr>
<td>Bioengineering</td>
<td>Industrial</td>
<td>Ocean</td>
</tr>
<tr>
<td>Ceramic</td>
<td>Manufacturing</td>
<td>Petroleum</td>
</tr>
<tr>
<td>Chemical</td>
<td>Materials</td>
<td>Software</td>
</tr>
<tr>
<td>Civil</td>
<td>Mechanical</td>
<td>Surveying</td>
</tr>
<tr>
<td>Construction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electrical, Electronic, Computer</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Technology Accreditation Criteria**

Criteria for 1999-2000 for 4-year and 2-year engineering technology programs illustrate the prescriptive approach previously applied, although revisions were in hand at the time of writing:

**Associate Degree Programs for Engineering Technicians:** 2-year associate degree programs:

- 64 semester hour credits in 2 years full-time or equivalent.
- 32 semester hours of technical studies in sciences, specialties and electives.
- 16 semester hours: at least 4 basic sciences and 8 mathematics, and remainder not in programming.
- 9 semester hours, at least 6 in communication, and some in social sciences and/or humanities.
- 7 semester hours in an integrated program of engineering technology or related areas, including using computers in solving technical problems, to prepare for engineering technician functions.

**Bachelor Degree Programs for Engineering Technologists:** 4-year bachelor degrees:

- 124 semester hour credits for a baccalaureate degree.
- 48 semester hours in technological studies including technical sciences, specialties and electives.
- 24 semester hours, at least 8 basic science and 12 mathematics in applicable program. Remainder in either.
- 24 semester hours, at least 9 communications and 8 social sciences or humanities, remainder in either.
- 28 semester hours in integrated program to prepare for engineering technologist functions, including using the computer on technical problems and additional studies in engineering technology or related areas.

ABET encourages innovative or non-traditional programs providing attributes as set in Table 13-5. A new approach devolves responsibility to the teaching institution to ensure adequate attention and time to each component. Technical content is expected to focus primarily on the applied science and engineering in the technological spectrum closest to product improvement, manufacturing, construction and engineering operations. Specific curriculum statements are:

- Mathematics: Algebra and trigonometry and an introduction to higher level mathematics in an associate degree program, and calculus for bachelor programs.
- Physical and Natural Science: Basic sciences may include physics, chemistry, and the life and earth sciences in accordance with program needs.
- Technical Content: Skills, knowledge, methods, procedures, and techniques, including integrating experiences, use of analytical or measurement equipment, competence in standard design practices, tools and techniques, and competence in computer applications.
- Communications: Written and oral technical reports, interpersonal skills required for teamwork, and the literature of the particular technology.
- Social Sciences/Humanities: A broad perspective on global and societal impacts of technology.
Articulation between associate and bachelor technology programs is encouraged, but there are no provisions for articulation to professional engineering degrees. Some technology programs comprise a single 4-year structure while others are 2 + 2 or 3 + 1 plans. Some focus on continuation of the associate degree technical specialty whereas others are broader interdisciplinary programs, but added studies predominantly in management do not make an engineering technology program. Additional accreditation criteria are defined for the specialisms in Table 13-7.

<table>
<thead>
<tr>
<th>Engineering Technology Programs Accredited by ABET</th>
<th>Specialisms for which ABET Special Program Criteria are Defined</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Conditioning</td>
<td>Construction</td>
</tr>
<tr>
<td>Architectural</td>
<td>Drafting/Design (Mechanical)</td>
</tr>
<tr>
<td>Automotive</td>
<td>Electrical/Electronic(S)</td>
</tr>
<tr>
<td>Bioengineering Technology</td>
<td>Environmental</td>
</tr>
<tr>
<td>Chemical</td>
<td>Industrial</td>
</tr>
<tr>
<td>Civil</td>
<td>Instrument/Measurement/Control</td>
</tr>
<tr>
<td>Computer</td>
<td>Manufacturing</td>
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<td></td>
<td>Marine</td>
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<tr>
<td></td>
<td>Mechanical</td>
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<td></td>
<td>Mining</td>
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<td></td>
<td>Nuclear</td>
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<tr>
<td></td>
<td>Surveying</td>
</tr>
<tr>
<td></td>
<td>Telecommunications</td>
</tr>
</tbody>
</table>

Analyses of Courses

**Professional Engineering Courses**

Selected civil and electrical courses in the UK and USA have been analysed to enable findings to be related to Australian courses. The courses in the UK reflect the flexible criteria of the EC and a higher entrance standard than in US and Australia. Three universities present examples: Imperial College of Science and Technology in London offers only the MEng, the University of Newcastle upon Tyne in the industrialised North offers an integrated BEng-MEng program, and the University of Sussex in the South specialises in electrical engineering and differentiates the MEng in extending from the BEng program. The two universities in the US offer typical ABET accredited BS engineering courses in civil and electrical engineering. Table 13-8 summarises studies to enable approximate comparisons with Australian 4-year courses on page 54.

Taking account of the higher level at entry in the UK, relative to Australian education the MEng route is equivalent to 5 years full-time study. All UK and US courses include similar content in mathematics, science, computing and engineering science, in the US about half the normal 4-year course. The UK BEng courses include a little more in such studies, and much more in design and applications than in the US courses, explained by greater attention to laboratory work in the UK. The MEng courses include extensive studies in design and applications, the equivalent of some 60 to 70 per cent of a normal Australian 4-year course.

About one fifth of the 4-year professional engineering course in USA is devoted to communication, economics and general studies, in keeping with pre-2000 ABET criteria. In the examples none of this material is directed to the management of engineering functions. The large foundation studies and general education components in the US courses leave room for only about one third of the course in engineering applications and design, but the more flexible new ABET criteria may permit increased concentration on advanced engineering studies. While the US courses exhibit uniformity under the existing ABET criteria, courses in the UK display differences in emphasis. At Imperial College and Newcastle, study of foreign language is a feature, but management studies are minimal except in the MEng civil courses at Newcastle and in electrical engineering at Sussex. The BEng courses at Newcastle and Sussex include 3 to 5 percent in management studies.

**Technology Courses**

Two institutional examples of ABET accredited technology courses in USA were analysed. Those at Alabama provide direct comparisons with professional engineering courses, while those at the Metropolitan State College at Denver illustrate technical institute programs. In each case lower entry criteria in mathematics point to a less analytical approach than in professional engineering courses. Distribution of content is varied, and there are greater proportions in management and general education studies. The proportion of Level 1 and 2 studies also is high in technology courses.
Comparison with Australia

Engineering in the UK

The Engineering Council is concerned with the educational formation and programs of Structured Initial Professional (sic) Development for the three work-force categories, in a historical situation that would seem prescriptive in Australia.\(^7\) The term 'engineer' is applied to the occupation described as 'Incorporated Engineer', but in Australia, the US and elsewhere described as 'engineering technologist.' Education for Incorporated 'Engineers' corresponds closely with practices in Australia for 3-year BTech degrees. There is no provision in the UK for a competency-based route without added education: recognition of mature unqualified candidates includes a searching assessment of the knowledge base. The examination set by the EC for a professional engineering qualification has no counterpart in Australia.

The Occupational Standards in engineering in the UK present accessible and useable definitions of professional roles in engineering. Educational and initial professional development requirements differentiate CEng from IEng, although more ambiguously than in Australia, with likelihood of greater difficulty in employment in differentiating the roles of the two work force categories when engaged on normal engineering work. Apart from the added year of education for the professional engineer, the only differentiating characteristic is an expectation that the professional engineer will fly higher and grapple with broader issues when work requires such effort. Australian Competency Standards provide more explicit guidance.

Engineering in the USA

The highly organised large-scale US accreditation process of ABET is concerned with education for the three work-force categories in a historical situation in which prescriptive policies have been accepted as the norm, but where concentration on outcomes now is evident. ABET is not concerned with experiential development beyond graduation. There is no ambiguity in ABET policies concerning the identity of professional engineers, engineering technologists and engineering technicians (para-professionals). Philosophies concerning formation of engineering technologists correspond closely with Australia practices for 3-year BTech degrees. The ABET approach to 2-year technical qualifications is much more focussed upon education in fundamentals than is the Australian approach over which IEAust has little influence.

The examination route of the EC for CEng status has no counterpart in the US. The examination route in the US for mature unqualified candidates for registration is described in Lloyd (1991). The educational requirements that differentiate engineers from technologists in the US are ambiguous in that each requires a 4-year degree, with likely difficulty in employment in differentiating of roles when graduates engage in normal engineering work, even though the professional engineer is educated in greater depth. Australian education for technologists is one year less than for engineers, and Competency Standards provide explicit interpretations of the nature of the work roles of the two categories, although the new approach to definition of attributes in the US is along similar lines to that of the IEAust.

Table 13-8

<table>
<thead>
<tr>
<th>Category of Studies</th>
<th>Maths etc Note(1)</th>
<th>Design &amp; Applic</th>
<th>Mangt &amp; General</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>United Kingdom</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MEng</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Imperial College, Civil</td>
<td>51</td>
<td>69</td>
<td>9</td>
<td>129</td>
</tr>
<tr>
<td>Newcastle, Civil</td>
<td>53</td>
<td>60</td>
<td>16</td>
<td>129</td>
</tr>
<tr>
<td>Newcastle, Electrical</td>
<td>60</td>
<td>57</td>
<td>7</td>
<td>124</td>
</tr>
<tr>
<td>Sussex, Electrical</td>
<td>52</td>
<td>57</td>
<td>22</td>
<td>131</td>
</tr>
<tr>
<td>Average</td>
<td>54</td>
<td>61</td>
<td>14</td>
<td>128</td>
</tr>
<tr>
<td><strong>BS Engineering</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alabama A&amp;M U, Civil</td>
<td>46</td>
<td>33</td>
<td>21</td>
<td>100</td>
</tr>
<tr>
<td>Alabama A&amp;M U, Elec</td>
<td>46</td>
<td>32</td>
<td>21</td>
<td>99</td>
</tr>
<tr>
<td>Carnegie Melon U, Civil</td>
<td>48</td>
<td>33</td>
<td>23</td>
<td>104</td>
</tr>
<tr>
<td>Carnegie Melon U, Elec</td>
<td>55</td>
<td>27</td>
<td>20</td>
<td>102</td>
</tr>
<tr>
<td>Average</td>
<td>49</td>
<td>31</td>
<td>21</td>
<td>101</td>
</tr>
<tr>
<td><strong>BS Eng Technology</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alabama A&amp;M U, Civil</td>
<td>40</td>
<td>27</td>
<td>33</td>
<td>100</td>
</tr>
<tr>
<td>Alabama A&amp;M U, Elec</td>
<td>39</td>
<td>33</td>
<td>28</td>
<td>100</td>
</tr>
<tr>
<td>Metro State College, Civil</td>
<td>46</td>
<td>43</td>
<td>10</td>
<td>99</td>
</tr>
<tr>
<td>Metro State College, Elec</td>
<td>52</td>
<td>31</td>
<td>21</td>
<td>104</td>
</tr>
<tr>
<td>Average</td>
<td>44</td>
<td>34</td>
<td>23</td>
<td>101</td>
</tr>
</tbody>
</table>

(1) Mathematics, science, computing, engineering science.
Relative Educational Standards and Approaches

The differentiation of the two professional categories is clear in Australia by reference to the occupational titles, and to the length and designations of the benchmark courses for each category. Even though there is educational differentiation in the UK, inclusion of 'engineer' in occupational titles and designations of degree programs create confusion. In the US care is taken by ABET to differentiate the educational objectives and criteria for professional engineers from engineering technologists, but because both programs are 4 years and lead to Bachelor of Science degrees, there is ambiguity in the work place and in public perceptions.

Education for professional engineers follows similar patterns in UK, USA and Australia. Studies in mathematics, science, computing and engineering science are similar in scope and depth. Australian accreditation policies require explicit attention to engineering management, but the requirement is honored in the breach by many, and the new criteria water down the previously specified ideal of 10 per cent. The approach to engineering management content varies in the UK: some MEng courses include a good deal while others include little. Courses in the US generally have included little management studies but paid great attention to general studies, but this might change. Australian and UK courses include more attention to design laboratory work than do US bachelor degree courses. General conclusions could be stated for professional engineering education as:

- In the UK, the new MEng is approximately equivalent to a 5-year course from the normal entry criteria applicable in Australia and the USA, making engineering education generally in line with Europe. While courses are based upon foundation studies similar to those in USA and Australia, design and applications are more extensive and reach greater depth.
- In the USA, the BS in Engineering provides less studies in design and applications than in UK or Australia, but generally US courses are of similar depth to Australian courses.

Education for engineering technologists follows less similar patterns. Studies in mathematics, science, computing and engineering science, and attention to engineering management, vary considerably. General conclusions for engineering technology education are:

- In the UK, the new benchmark of a 3-year degree will bring engineering technology education generally into line with USA. While courses are based upon foundation studies roughly similar to those in USA and Australia, design and applications are more extensive than in the USA. Occupational identity is made ambiguous by the term 'Incorporated Engineer'.
- In the USA, the benchmark BS in Engineering Technology provides design and engineering applications less extensive than in UK, but of similar depth to Australian BTech courses. Occupational identity is made ambiguous by the fact that the 4-year Bachelor of Science is the benchmark for both professional engineers and engineering technologists.

Notes to Chapter 13

1 Accreditation in the US in relation to the engineering societies and registration is described in Lloyd (1991).
2 Abbreviated from SARTOR 1996. The EC does not refer to 'attributes', but the idea is similar.
4 Information under this heading was provided from Sheffield Hallam University by Robin Acheson.
5 The UK PELF estimated by Rice and Lloyd is conservative; it includes university graduates only, while Chartered Engineers include an unknown proportion of older engineers qualified by other means.
6 The word 'attribute' is not used, but requirements expressed are similar to the attributes defined by IEAust.
7 Engineering Council publications apply the word 'professional' loosely to the engineering technician.
Chapter 14
Demographic Change in Professional Engineering

By Michael R Rice

Introduction
The last decade of the 20th Century was one of significant change for the professional engineering population in Australia. The number of commencements in engineering courses increased significantly, the annual number of engineering graduates increased by more than 75 per cent, and immigration continued as a significant input to the Professional Engineering Labour Force (PELF).

In the globalised world of engineering, between 1988/89 and 1992/93 more than 15,000 foreign born engineers became permanent settlers, almost equal to the number of Australians who graduated in engineering in the same period. In the ten years 1988 to 1998 more than 23,000 engineers arrived in Australia as permanent settlers. At the same time, the number of Australian engineers departing permanently for overseas showed a marked increase. These engineers are likely to be those with capabilities marketable in the international sphere, therefore the real loss is greater than the numbers would indicate.

Other significant changes were the rapid increase in the PELF as well as the greater involvement of women in engineering courses at all levels. The size of the PELF is likely to exhibit continued growth in the first decade of the 21st Century, although the rapid growth of the 1990s is not likely to be repeated. By 2010 we expect that the rate of growth of the profession will decline to less than 2 per cent per annum. The representation of women in PELF will continue to increase. However, without an increase in the tendency of women to undertake engineering studies, the proportion of women will be asymptotic to about 15 per cent in the long term.

Methodology
The methodology used for computing the Professional Engineering Labour Force (PELF) is essentially the same as that used in Rice and Lloyd (1990 and 1991). In the spreadsheet model, in each year the number of professional engineers in previous year is increased by the number of new Australian engineering graduates and the net number of immigrant engineers, with adjustments for losses from deaths and retirements. The annual number of graduates was obtained from data provided by the Department of Education, Training and Youth Affairs, and adjusted to include only Australians who graduated in professional engineering programs accredited by IEAust.

The annual numbers of immigrant and emigrant engineers were provided by the Department of Immigration and Multicultural Affairs. These data were based on the self descriptions of their occupations by the persons concerned. In the absence of other data the possibility of error arising from such self-description had to be accepted. However, comparison of the immigration information with information regarding the recognition of overseas qualifications by IEAust indicates that the likely magnitude of any such error was acceptable for the purposes of the estimates.

The estimates of deaths before retirement were based on age-specific death rates applicable to the Australian population. No provision is made to account for the loss to the profession arising from permanent incapacitation arising from illness or injury, and this is another source of conservatism. The model provided the age distribution in each annual cohort of the PELF, therefore data concerning age retirements were automatically provided.

Bachelor Degrees in Engineering
Course Completions at Bachelor Degree Level
In an earlier publication (Rice & Lloyd, 1990) we provided data on the number of annual course completions of Australian engineering students at bachelor degree level up to 1989. In the following the discussion is based on data derived on the same basis as that we used previously. These data were developed from the information relating to individual institutions provided by the Department of Education, Employment and Youth Affairs (DETYA). The numbers of graduates include only those completing engineering courses that were accredited by the IEAust as professional engineers. Graduates in metallurgy, surveying and cartography are not included.

Table 14-1 shows the number of completions by Australian students in engineering courses from 1990 onwards. These data indicate that the number of course completions at bachelor degree level has increased by 77 per cent in the period 1990-1998 while the number of graduates per million population has increased by 61 per cent.
At first glance, total engineering completions and the ratio of completions to population might appear to have grown to unprecedentedly high levels in the period. However, in reality this growth represents a recovery from a marked decline in the number of engineering completions between 1976 and 1981. It was not until 1992 that the number of engineering graduates relative to population exceeded the levels prevailing in the mid-1970s. The proportion of successful students in recent years is the basis for our extrapolation of future graduation rates.

Completion Rates
While many fields of study exhibit low completion rates, engineering courses are characterised by relatively lower completion rates than some others. Undoubtedly, the crude comparison of the number of completions with the number of commencements at some appropriate time in the past leaves much to be desired as a true measure of the completion rate. However, in the absence of a comprehensive longitudinal study, this approach provides some indication of the magnitude of the proportion of commencing students who finally succeed in completing their studies.

Commencements in Bachelor Degrees
Table 14-2 presents data for commencements by Australian students in ‘engineering and surveying’ for the period to 1999. The DETYA data on which this table is based include commencements in cartography, surveying and metallurgy. Therefore the level of commencements is a little greater than for engineering students alone. It is noteworthy that the DETYA data indicate that there was a levelling off in the number of commencements in engineering, surveying and metallurgy following 1994. Between 1994 and 1997 commencements increased by only 8 per cent, followed by a slight decline after 1997.

Course Completions in Higher Degrees
It should be noted that in the following sections the data were derived from DETYA reports and relate to what is designated as one of the ‘Fields of Study’ employed by that organisation in reporting its data. In the case of engineering the Field of Study includes engineering, surveying, cartography and metallurgy. However, engineering predominates, and the DETYA data provide a good, if not precise, indication of the levels of commencements and completions in undergraduate and postgraduate study in engineering.
Completions in Master Degrees
Table 14-3 shows completions by Australian students in engineering, surveying and metallurgy at master degree level in the period 1990-1998, by both coursework and research. The proportion of degrees obtained by coursework increased from 60 per cent in 1990 to 76 per cent in 1997. This analysis does not include the participation of engineers in postgraduate studies in other fields, particularly in MBA studies as noted in Chapter 12. There has been a four-fold increase in the number of persons completing master degrees in engineering, surveying and metallurgy in relatively short period of eight years after 1990, most of the increase being accounted for by degrees by coursework. The increase continued to 1997 when 793 persons completed master degrees. Current data concerning commencements indicate that a high level of completions of master degrees will continue for a year or two at least. It has been suggested that the increase was due, at least in part, to the depressed employment prospects of engineers in the period of recession that commenced in late 1989, as discussed further below. Another contributing factor is the increased availability of coursework programs by off-campus studies, as noted in Chapter 12.

Table 14-3
Completions in Master Degrees in Engineering, Surveying and Metallurgy: 1990-1998

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of completions</th>
<th>Completions per million population</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>172</td>
<td>10.1</td>
</tr>
<tr>
<td>1991</td>
<td>368</td>
<td>21.3</td>
</tr>
<tr>
<td>1992</td>
<td>511</td>
<td>29.2</td>
</tr>
<tr>
<td>1993</td>
<td>581</td>
<td>32.9</td>
</tr>
<tr>
<td>1994</td>
<td>585</td>
<td>32.8</td>
</tr>
<tr>
<td>1995</td>
<td>650</td>
<td>36.0</td>
</tr>
<tr>
<td>1996</td>
<td>688</td>
<td>37.6</td>
</tr>
<tr>
<td>1997</td>
<td>793</td>
<td>42.8</td>
</tr>
<tr>
<td>1998</td>
<td>731</td>
<td>38.5</td>
</tr>
</tbody>
</table>

Completions in Doctoral Degrees
Completions of doctoral degrees in engineering, surveying and metallurgy by Australian students between 1990 and 1998 are shown in the Table 14-4. As for master degrees, there has been a marked increase in the rate of completion since 1990. Relative to population, the number of degrees has quadrupled over a period of eight years. In absolute numbers the number of doctoral degrees has increased four-fold. The greatest rate of growth in the number of those completing doctoral degrees in engineering, surveying and metallurgy has been exhibited in the period 1993-1997. This also is consistent with the suggestion that, because of the reduction of job opportunities during the recession of the early 1990s, some engineering graduates turned to post-graduate study as a better option than unemployment.

Table 14-4
Completions in Doctoral Degrees in Engineering, Surveying and Metallurgy: 1990-1998

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of Completions</th>
<th>Completions per million population</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>76</td>
<td>4.4</td>
</tr>
<tr>
<td>1991</td>
<td>115</td>
<td>6.7</td>
</tr>
<tr>
<td>1992</td>
<td>112</td>
<td>6.4</td>
</tr>
<tr>
<td>1993</td>
<td>121</td>
<td>6.8</td>
</tr>
<tr>
<td>1994</td>
<td>166</td>
<td>9.3</td>
</tr>
<tr>
<td>1995</td>
<td>198</td>
<td>11.0</td>
</tr>
<tr>
<td>1996</td>
<td>291</td>
<td>15.9</td>
</tr>
<tr>
<td>1997</td>
<td>325</td>
<td>17.5</td>
</tr>
<tr>
<td>1998</td>
<td>319</td>
<td>16.8</td>
</tr>
</tbody>
</table>

The current level of doctoral commencements indicates that it is likely that the number of doctoral completions will continue to increase over the next few years. One interesting aspect of the increased number of doctoral completions is that, relative to population, Australians complete doctoral degrees in engineering at about twice the rate prevailing for American nationals in the United States. In 1990 the number of persons completing doctorates was equal to 3.5 per cent of the number completing bachelor degrees four years previously. In the preceding decade this proportion had, on average, been somewhat lower. By 1997 this ratio had increased to 6.7 per cent but by 1998 it had declined to 6.0 per cent. Data relating to commencing candidates indicate that the latter level will prevail for the next three or four years at least.
Commencements in Higher Degrees

Commencements in Master Degrees

The numbers of commencements by Australians in master degree programs in engineering, surveying and metallurgy in the years 1990-1998 are shown in the Table 14-5. It is apparent that there was a substantial increase in commencements in the first three years of the decade. Following that, commencements declined rather rapidly. This pattern also is consistent with the hypothesis that, during the recession of the early 1990s postgraduate study was seen as an alternative to unemployment by a considerable number of engineering graduates.

In the peak year for commencements in master degree programs, 1993, 1,414 students commenced. While not all commencing students in master degree programs were engineering graduates from the previous year, a calculation based on such a simplifying assumption would indicate that 41 per cent of the previous year’s graduates embarked on postgraduate study in master degree programs. By 1999 this notional proportion had declined to 18 per cent, a proportion reasonably consistent with the situation that prevailed before the recession.

Table 14-5
Commencements in Master Degrees in Engineering, Surveying and Metallurgy: 1990-1998

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of commencements</th>
<th>Commencements per million population</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>671</td>
<td>39.3</td>
</tr>
<tr>
<td>1991</td>
<td>1,099</td>
<td>63.6</td>
</tr>
<tr>
<td>1992</td>
<td>1,404</td>
<td>80.1</td>
</tr>
<tr>
<td>1993</td>
<td>1,414</td>
<td>80.0</td>
</tr>
<tr>
<td>1994</td>
<td>1,276</td>
<td>71.5</td>
</tr>
<tr>
<td>1995</td>
<td>1,248</td>
<td>69.1</td>
</tr>
<tr>
<td>1996</td>
<td>1,116</td>
<td>61.0</td>
</tr>
<tr>
<td>1997</td>
<td>1,151</td>
<td>62.1</td>
</tr>
<tr>
<td>1998</td>
<td>1,058</td>
<td>56.4</td>
</tr>
<tr>
<td>1999</td>
<td>1,018</td>
<td>53.7</td>
</tr>
</tbody>
</table>

Commencements in Doctoral Degrees

The number of Australians commencing doctoral programs of study in engineering, surveying and metallurgy in the years 1990-1999 is shown in Table 14-6. It is apparent that there was a substantial increase in commencements in the first four years of the decade. As in the case of commencements in master degree programs this pattern too is consistent with the hypothesis that, in the early 1990s postgraduate study was seen as an alternative to unemployment by a considerable number of engineering graduates.

In the peak year for commencements in master degree programs, 1993, 488 Australians commenced doctoral programs in the engineering field of study. While it is debatable that all commencing candidates in doctoral programs were engineering graduates from the previous year, once again a calculation based on such an assumption indicates that 14 per cent of 1993 bachelor degree graduates had embarked on doctoral programs. By 1999 this notional proportion had declined to 9 per cent. This is much higher than the level that had prevailed at the beginning of the decade.

Table 14-6
Commencements in Doctoral Degrees in Engineering, Surveying and Metallurgy: 1990-1998

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of commencements</th>
<th>Commencements per million population</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>171</td>
<td>10.1</td>
</tr>
<tr>
<td>1991</td>
<td>247</td>
<td>14.3</td>
</tr>
<tr>
<td>1992</td>
<td>403</td>
<td>23.0</td>
</tr>
<tr>
<td>1993</td>
<td>488</td>
<td>27.6</td>
</tr>
<tr>
<td>1994</td>
<td>453</td>
<td>25.4</td>
</tr>
<tr>
<td>1995</td>
<td>432</td>
<td>23.9</td>
</tr>
<tr>
<td>1996</td>
<td>447</td>
<td>24.5</td>
</tr>
<tr>
<td>1997</td>
<td>511</td>
<td>27.6</td>
</tr>
<tr>
<td>1998</td>
<td>491</td>
<td>26.2</td>
</tr>
<tr>
<td>1999</td>
<td>486</td>
<td>25.6</td>
</tr>
</tbody>
</table>
Specialisms in Engineering

Since the 1970s there have been changes in the distribution of graduates between engineering specialisms. The proportion of annual completions of first degrees in engineering in the period 1989-1998 in each branch of engineering is shown in Table 14-7.

The most significant trend apparent from the table is the small but perceptible decline in civil engineering from 20.1 per cent in 1989 to 17.9 per cent in 1998, while the absolute numbers increased from 602 in 1989 to 944 in 1998. The decreasing proportion of civil engineering graduates continued a trend that became apparent in the previous decades: annual civil engineering qualifications declined from about 36 per cent of all engineering graduates and diplomates in 1977 to 24.4 per cent of civil engineering graduates in 1987 (Rice and Lloyd 1990, pp. 57-8).

The combined fields of electrical engineering and electronic, communications and computer engineering increased from 31.7 per cent of all graduates in 1989 to a peak of 36.2 per cent in 1991 and then apparently declined to 24.8 per cent in 1998. However, the number of graduations increased from 947 to 1,308 in the ten-year period.

Caution has to be exercised in interpreting the trends observable in Table 14-7, especially in comparisons with previous decades. No degrees are actually conferred in the DETYA category ‘General Engineering’, but in Table 14-7 this category ranges widely as a percentage of all engineering graduations. Many such graduates should be counted in one of the specialisms. For example, most environmental engineering courses are related to civil engineering, while a few are closer to chemical engineering. There are few courses in industrial engineering, and perhaps this category includes manufacturing, which would be better included in mechanical. Is software engineering included in ‘computer’ or ‘other’? Thus, conclusions drawn from Table 14-7 could be misleading. Ultimately, all that can be said is that civil engineering no longer predominates in engineering graduations and that electrical, electronic and computer engineering is the largest field. Further light is thrown in this question in Chapter 7.

The DETYA report relating to 1998 provides tabulated data concerning the total student load in Equivalent Full-time Students Units (EFTSU) in the various ‘discipline groups’. While EFTSU does not precisely equate to the actual number of students it may be regarded as an acceptable approximation for the purposes of comparing the proportions of students undertaking studies in the various specialisms of engineering. In addition, the most recent DETYA report provides information regarding the EFTSU for commencing students relating to the various engineering specialisms. These latter data do not necessarily indicate outcomes, but rather intentions, and provide only indicative information as to the likely distribution of graduates between engineering specialisms in the short term future, say three years from now.

The comparison that these data provide is of interest in showing the profound changes in the distribution of new graduates between engineering specialisations over the quarter century between 1977 and the early years of the new century, as summarised in Table 14-8. The distribution

![Table 14-7]

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Aeronautical</td>
<td>2.0</td>
<td>1.7</td>
<td>2.8</td>
<td>2.3</td>
<td>2.6</td>
<td>2.9</td>
<td>3.2</td>
<td>2.1</td>
<td>2.6</td>
<td>2.9</td>
</tr>
<tr>
<td>Civil (and Structural)</td>
<td>20.1</td>
<td>21.0</td>
<td>22.2</td>
<td>20.1</td>
<td>19.4</td>
<td>18.4</td>
<td>18.5</td>
<td>17.0</td>
<td>17.5</td>
<td>17.9</td>
</tr>
<tr>
<td>Chemical</td>
<td>5.6</td>
<td>6.9</td>
<td>6.7</td>
<td>7.7</td>
<td>6.4</td>
<td>7.1</td>
<td>6.8</td>
<td>7.5</td>
<td>6.9</td>
<td>7.0</td>
</tr>
<tr>
<td>Electrical, Electronic and Computer</td>
<td>31.7</td>
<td>31.5</td>
<td>36.2</td>
<td>32.0</td>
<td>32.0</td>
<td>32.4</td>
<td>26.5</td>
<td>26.9</td>
<td>28.6</td>
<td>24.8</td>
</tr>
<tr>
<td>Industrial</td>
<td>2.9</td>
<td>2.5</td>
<td>3.0</td>
<td>3.2</td>
<td>2.8</td>
<td>3.3</td>
<td>3.7</td>
<td>4.1</td>
<td>4.0</td>
<td>3.4</td>
</tr>
<tr>
<td>Mechanical</td>
<td>16.8</td>
<td>19.2</td>
<td>18.7</td>
<td>19.6</td>
<td>16.9</td>
<td>16.6</td>
<td>16.5</td>
<td>14.9</td>
<td>15.3</td>
<td>15.4</td>
</tr>
<tr>
<td>Mining</td>
<td>2.3</td>
<td>2.6</td>
<td>3.0</td>
<td>2.6</td>
<td>3.2</td>
<td>3.1</td>
<td>2.9</td>
<td>3.4</td>
<td>3.3</td>
<td>3.1</td>
</tr>
<tr>
<td>General and Other</td>
<td>18.6</td>
<td>14.6</td>
<td>7.4</td>
<td>12.3</td>
<td>16.8</td>
<td>16.1</td>
<td>21.9</td>
<td>24.1</td>
<td>21.7</td>
<td>25.5</td>
</tr>
</tbody>
</table>

Note: The table is dependent upon somewhat imprecise definitions of the engineering specialisms. The very large category ‘General and Other’ includes many graduates more appropriately included elsewhere.
of new engineering graduates between engineering specialisms has changed so markedly over the last quarter of the 20th century that any error arising from the re-categorisation within the field of engineering is likely to be insignificant. Table 14-8 confirms the trend away from civil, towards electronic and computer engineering.

### Table 14-8

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Aeronautical</td>
<td>1.0</td>
<td>1.7</td>
<td>2.9</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Chemical</td>
<td>5.8</td>
<td>6.9</td>
<td>7.1</td>
<td>6.4</td>
<td>5.0</td>
</tr>
<tr>
<td>Civil and Structural</td>
<td>36.1</td>
<td>21.1</td>
<td>18.5</td>
<td>18.1</td>
<td>12.9</td>
</tr>
<tr>
<td>Electrical, Electronic and Computing</td>
<td>28.7</td>
<td>31.3</td>
<td>32.3</td>
<td>38.9</td>
<td>40.7</td>
</tr>
<tr>
<td>Industrial</td>
<td>2.5</td>
<td>2.6</td>
<td>3.2</td>
<td>3.3</td>
<td>2.9</td>
</tr>
<tr>
<td>Mechanical</td>
<td>21.0</td>
<td>19.3</td>
<td>16.7</td>
<td>18.9</td>
<td>16.2</td>
</tr>
<tr>
<td>Mining</td>
<td>1.7</td>
<td>2.5</td>
<td>3.1</td>
<td>2.4</td>
<td>2.1</td>
</tr>
<tr>
<td>General and Other</td>
<td>3.2</td>
<td>14.6</td>
<td>16.2</td>
<td>12.0</td>
<td>21.3</td>
</tr>
</tbody>
</table>

Notes: 1. Relates to total student load (EFTSU) for bachelor degree level of engineering discipline group. 2. Relates to commencing student load (EFTSU) for bachelor of engineering discipline group.

### Professional Engineering Population

#### Distribution by Specialism

There are no reliable data to indicate the distribution of engineers by specialism in the Professional Engineering Labour Force (PELF), but information included in the regular APESMA reports of six monthly salary surveys enables estimates of the trends that have taken place in the survey sample population, drawn from the membership of APESMA and IEAust. The following table summarises the changes that have occurred in the period June 1989 to June 1999. The estimates are based on five-point moving averages. It should be noted that the questionnaire in the survey instrument requested the respondent to state the branch of engineering in which he or she received his or her qualification.

### Table 14-9

<table>
<thead>
<tr>
<th>Engineering Specialism</th>
<th>1989</th>
<th>1999</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aeronautical</td>
<td>1.0</td>
<td>1.6</td>
</tr>
<tr>
<td>Chemical</td>
<td>3.2</td>
<td>5.2</td>
</tr>
<tr>
<td>Civil</td>
<td>44.8</td>
<td>35.0</td>
</tr>
<tr>
<td>Electronic, computer &amp; communications</td>
<td>25.2</td>
<td>30.3</td>
</tr>
<tr>
<td>Industrial</td>
<td>1.0</td>
<td>1.7</td>
</tr>
<tr>
<td>Mechanical</td>
<td>22.4</td>
<td>19.9</td>
</tr>
<tr>
<td>Mining</td>
<td>0.6</td>
<td>0.8</td>
</tr>
<tr>
<td>Materials etc.</td>
<td>0.4</td>
<td>1.3</td>
</tr>
<tr>
<td>Other</td>
<td>1.4</td>
<td>4.3</td>
</tr>
<tr>
<td>Total</td>
<td>100.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>

The survey population involved may not be representative of the total Australian population because of the past tendency for civil engineering to be better represented than other specialisms in the two organisations from which the survey samples are drawn. However, even with this in mind, the decline over the decade in the proportion of respondents in civil engineering and the increase in the proportion in electrical/electronic and computer engineering are noteworthy.

On the basis of the current distribution of engineering students by specialism, it is evident that the days of civil engineering as the predominant specialism are long passed. As indicated in Chapter 7, the decrease in the teaching of electrical power engineering also leads to a prediction of a similar decline in that traditional specialism, while electronic and computer engineering are in-
creasing rapidly. If these trends persist, electronic and computer engineering must become the predominant branch of engineering in rather less than 10 years. There is a profound message for the professional associations here.

An implication of the above findings is that, in the period 1989-1999 the number of persons in the PELF with civil engineering qualifications has increased by less than 10 per cent. This is less than the increase in the Australian population in the same period. In consequence, for the first time in Australian experience the number of civil engineers relative to the population has declined, and the decline can be expected to continue. The magnitude and consequences of this decline, and by how much it is being counterbalanced by environmental engineering, warrant investigation, but such an enquiry is beyond the scope of this book.

Women in Engineering

For some time it has been a matter of concern that the engineering profession has failed to attract women to the same extent as certain other professional occupations. Currently, about one-sixth of Australian bachelor degree engineering graduates are women. This is much lower than the proportion of women who graduate in most other fields of study. Table 14-10 indicates the current situation for seven fields of study. It should be noted that “field of study” is not necessarily equivalent to a specific discipline, and that there may be sub-categories in which the representation of women differs markedly from the broad category within which it is contained. Physics is one such case. There is reason to believe that the representation of women in physics is closer to that of engineering while in the entire science field of study the representation of women is nearly equal that of men. Currently 47% of Australian bachelor degrees in science are awarded to women. A somewhat similar situation also prevails in the United States. Table 14-10 shows that in several fields of study women graduates form the majority. In arts, the humanities and the social sciences, and in veterinary science, men are seriously under-represented.

<table>
<thead>
<tr>
<th>Field of study</th>
<th>Female percentages of bachelor degree graduates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Architecture, building</td>
<td>48.2</td>
</tr>
<tr>
<td>Arts, humanities and social sciences</td>
<td>69.7</td>
</tr>
<tr>
<td>Business administration etc.</td>
<td>48.2</td>
</tr>
<tr>
<td>Education</td>
<td>78.2</td>
</tr>
<tr>
<td>Law, legal studies</td>
<td>53.6</td>
</tr>
<tr>
<td>Science</td>
<td>46.6</td>
</tr>
<tr>
<td>Veterinary science</td>
<td>65.8</td>
</tr>
</tbody>
</table>

Data concerning the proportion of women engineering graduates in the total number of engineering graduates are available from an analysis of the information in the DETYA annual reports relating to higher education students. Table 14-11 shows the proportion of graduating bachelor, master and doctoral engineering, surveying and metallurgy students in the period 1990-1998. It is clear that the proportion of women engineering graduates at bachelor degree level increased quite rapidly and then plateaued at 14 to 15 per cent. As discussed below, it does not appear that this level will be exceeded to any great extent within the next two or three years.

The proportion of women engineering graduates at master degree level has increased fairly rapidly to much the same level as now prevails in the case of bachelor degrees. The indications are that this will not change very much for at least the next year or two. In the case of doctoral degrees it appears to be likely that the proportion of female doctoral graduates will increase further. Interestingly, the current trend in commencements at doctoral level by women engineering graduates indicates that they will, within the next few years, demonstrate a greater propensity to complete doctoral programs in engineering than men.

Participation in Engineering by Women

The proportion of female students commencing bachelor degree courses in engineering since 1992 has hovered around 13 to 14 per cent. In the case of master degrees the proportion of female commencing students demonstrated a steady increase until 1997 but has stabilised thereafter at approximately 16 per cent. However, there has been a steady increase in the proportion of women candidates commencing doctoral studies. In 1990 about 9 per cent of commencing doctoral students were women, while in 1998 the proportion was over 23 per cent. Therefore it is not unlikely that in
the longer term the proportion of women engineering academics will be higher than the proportion of women in the engineering profession. The consequences for engineering education and the profession itself are likely to be profound.

Table 14-11
Females as a Proportion Total Graduates in the Engineering Field of Study (Per Cent)

<table>
<thead>
<tr>
<th>Year</th>
<th>Women graduates as a proportion of the total number</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bachelor degree</td>
</tr>
<tr>
<td>1990</td>
<td>9.3</td>
</tr>
<tr>
<td>1991</td>
<td>9.7</td>
</tr>
<tr>
<td>1992</td>
<td>11.5</td>
</tr>
<tr>
<td>1993</td>
<td>12.6</td>
</tr>
<tr>
<td>1994</td>
<td>14.3</td>
</tr>
<tr>
<td>1995</td>
<td>13.8</td>
</tr>
<tr>
<td>1996</td>
<td>14.3</td>
</tr>
<tr>
<td>1997</td>
<td>14.9</td>
</tr>
<tr>
<td>1998</td>
<td>15.0</td>
</tr>
</tbody>
</table>

The relatively low representation of women in engineering courses has long been decried by feminist commentators. The situation has been attributed to discriminatory attitudes on the part of male academics, students and practising engineers. Setting that issue aside, the problem is not so much one of attracting women into engineering as attracting them to the more traditional fields of engineering. As discussed below, the issue is one of motivating women to undertake studies in mechanical, electrical/electronic and civil engineering as readily as they are attracted to chemical, environmental and materials engineering. The 1995 pattern of graduations is exhibited in the following Table 14-12.

Table 14-12
Females as a Proportion of all Engineering Graduates by Specialism (Per cent)

<table>
<thead>
<tr>
<th>Specialism</th>
<th>Proportion of graduates who are women</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aeronautical engineering</td>
<td>14</td>
</tr>
<tr>
<td><strong>Chemical engineering</strong></td>
<td><strong>35.7</strong></td>
</tr>
<tr>
<td>Civil engineering</td>
<td>16.2</td>
</tr>
<tr>
<td>Electrical, Electronic &amp; Computer Engineering</td>
<td>19.5</td>
</tr>
<tr>
<td>Industrial engineering</td>
<td>14.2</td>
</tr>
<tr>
<td>Marine engineering</td>
<td>0</td>
</tr>
<tr>
<td>Mechanical engineering</td>
<td>7.5</td>
</tr>
<tr>
<td>Mining &amp; Mineral Engineering</td>
<td>17.0</td>
</tr>
<tr>
<td>Engineering, general</td>
<td>13.6</td>
</tr>
<tr>
<td><strong>Engineering, other</strong></td>
<td><strong>38.3</strong></td>
</tr>
</tbody>
</table>

The table indicates that Australian women prefer some engineering disciplines to others. Chemical engineering is particularly popular. The data available also indicates that women are also well represented in “Engineering, other”, no doubt because this field includes materials and environmental engineering, both popular with women. It is easy to demonstrate that, if the representation of women in Australian engineering courses were raised to “world’s best practice” (27 per cent) without a simultaneous improvement in the popularity of engineering specialisms that women tend to avoid, the majority of graduates in chemical, materials and environmental engineering would be women. Mechanical, civil and electrical, electronic and computer engineering would continue to be almost exclusively male engineering specialisms. This is not a consequence that would have to be sought by those campaigning for the increased representation of women in the engineering profession.

Statements by some commentators on the tendency of women to opt for some specialisms in preference to others are not convincing. Could the real reason be that female choices reflect mistaken perceptions about engineering work, or are other influences at work? In the United States the pattern of the representation of graduating women in engineering specialisms is uncannily similar to that in Australia. And as in Australia, women shy away from physics but are well represented in chemistry. While not identical, the pattern in the UK bears some similarity to that in Australia. Fur-
thermore, data from a number of European countries indicate that in the early 1980’s similar effects were apparent there.

Two thoughts arise from these considerations. First, there is an absence of hard evidence to support the implication that male members of the profession in the above mentioned three English-speaking countries discriminate against women engineers and thus keep them away from the profession. It is therefore unreasonable to imply that this is occurring. Secondly, in view of the fact that there are substantial differences in the representation of women in the different specialties, any discrimination by male engineers towards female engineers would have to be specific to certain specialties. Not only that, but the message that such differences in behaviour did exist would have had to get back to the community in general if intending students were to be influenced in their choice of engineering specialism. These propositions are at variance with both common sense and the facts. Until the appropriate survey of intending women students has been done, opinions expressed on this issue are based on surmise and nothing else.

**Immigration and Emigration**

In the period 1989-2000 an unprecedentedly large number of immigrants with professional engineering qualifications settled in Australia. In the same period a significant number of engineers decided to settle permanently overseas. Table 14-13 summarises the data provided by the Department of Immigration and Multicultural Affairs. These data relate to ‘engineers and building professionals’ but the numbers in the latter category are relatively small. The same table also shows the relationship of the annual number of immigrant engineers to the number of Australian engineering graduates in that same year. In addition it shows the estimated number of Australian residents self-identifying as engineers, as a proportion of the Australian PELF.

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of permanent settlers</th>
<th>Number of permanent departures</th>
<th>Permanent settlers self-identified as engineers as a % engineering graduates</th>
<th>Permanent departures (self-identified as PEs) as % of PELF</th>
</tr>
</thead>
<tbody>
<tr>
<td>1988/89</td>
<td>2,693</td>
<td>315</td>
<td>89.2</td>
<td>n.a.</td>
</tr>
<tr>
<td>1989/90</td>
<td>2,720</td>
<td>442</td>
<td>91.5</td>
<td>0.46</td>
</tr>
<tr>
<td>1990/91</td>
<td>3,949</td>
<td>516</td>
<td>126.3</td>
<td>0.52</td>
</tr>
<tr>
<td>1991/92</td>
<td>3,356</td>
<td>490</td>
<td>95.5</td>
<td>0.48</td>
</tr>
<tr>
<td>1992/93</td>
<td>2,345</td>
<td>520</td>
<td>56.5</td>
<td>0.49</td>
</tr>
<tr>
<td>1993/94</td>
<td>1,605</td>
<td>505</td>
<td>35.4</td>
<td>0.46</td>
</tr>
<tr>
<td>1994/95</td>
<td>1,905</td>
<td>576</td>
<td>40.0</td>
<td>0.51</td>
</tr>
<tr>
<td>1995/96</td>
<td>2,038</td>
<td>603</td>
<td>41.1</td>
<td>0.51</td>
</tr>
<tr>
<td>1996/97</td>
<td>1,757</td>
<td>644</td>
<td>33.9</td>
<td>0.53</td>
</tr>
<tr>
<td>1997/98</td>
<td>1,664</td>
<td>701</td>
<td>31.7</td>
<td>0.59</td>
</tr>
<tr>
<td>1998/99</td>
<td>1,878</td>
<td>857</td>
<td>n.a.</td>
<td>0.68</td>
</tr>
<tr>
<td>1999/2000</td>
<td>2389</td>
<td>1059</td>
<td>n.a.</td>
<td>0.72</td>
</tr>
</tbody>
</table>

Source: Derived from data provided by the Department of Immigration and Multicultural Affairs, the Department of Education and Youth Affairs and our estimates of the PELF.

In the decade 1978/79-1987/88 the average annual number of engineers settling permanently in Australia was just under 1,000. Between 1988/89 and 1998/99 a total of 25,955 professional engineers arrived in Australia as permanent settlers, an average of 2,360 arrivals per annum. This is 78 per cent of the number of Australian graduates in engineering in the same period.

The fourth column of Table 14-13 indicates that in 1990/91 the number of permanent arrivals equalled 126.3 per cent of the number of Australians graduating in that year. This took place at the time that Australia was experiencing the early stages of the recession of the early 1990s. It is little wonder that the number of respondents to the regular APESMA salary surveys who reported that they were not employed rose from 2 to 7 per cent over the eighteen month period from December 1990 to June 1992. That figure is equivalent to an increase in the number of unemployed engineers of over 5,000. Despite representations by the IEAust and others, the government of the day appeared to take no action to stem the inward flow of migrant engineers. However, the extreme peak of immigration of engineers in 1990/91 has not recurred.

Table 14-13 indicates that the number of engineers leaving Australia to settle permanently in
other countries exhibited a marked increase over the eleven years 1988/89 to 1998/2000. As a consequence the net increase in the number of engineers from migration decreased from a peak of 3,433 in 1990/91 to 1,021 in 1998/99. It rose to 1,330 in 2000.

As a percentage of the PELF the increase in immigration is very significant. If the tendency for Australian engineers to emigrate continues its recent upward trend, the combination of this effect together with the continued increase in the PELF would result in the number of Australian engineers permanently departing Australia exceeding 1,500 every year within four years. Even if the proclivity of Australian engineers to emigrate holds steady at the average rate that has prevailed in the last three years, the number of engineers leaving Australia permanently would exceed 1,200 per year before 2010. Assuming that the rate of arrival of permanent immigrant engineers continues at the present average level, the net benefit from immigration would decline to under 1,200 per year.

There is an aspect of reliance on immigration that is largely ignored. If we assume that the average graduation age of Australian engineers is 23 years and a retirement age of 57, then the number of years worked between graduation and retirement is 34. If we assume that immigrant engineers are about 33 years of age on arrival in Australia, then their average working lives in Australia is some 24 years. Thus the equivalent contribution to the Australian PELF of the average immigrant engineer is about two-thirds that of an engineer who graduates in Australia. This estimate ignores the fact that, at the beginning, most immigrant engineers are not au fait with Australian engineering standards, materials and practices, and in many cases are not fluent in English. Therefore, most immigrant engineers do not begin to make a full contribution to engineering work for some time after they obtain employment. The additional factor is that many immigrant engineers take a considerable time to gain professional engineering employment, and a proportion of immigrant engineers never secure engineering employment. The conclusion, therefore, is that the practicable equivalent contribution of the average immigrant engineer to the Australian PELF is considerably less than two-thirds that of an engineer who graduates in Australia.

Professional Engineering Labour Force

The Computation Model

Using the model developed to compute the Professional Engineering Labour Force (PELF) set out in Rice and Lloyd (1990), we have updated our series for the supply of engineers of working age living in Australia. Computations are based on the numbers of annual Australian graduations and the net numbers of immigrant engineers tabulated above. The assumptions underlying the model and a brief description of the methodology employed are described below. PELF is defined as the number of working age persons living in Australia and possessing professional engineering qualifications acceptable to IEAust.

<table>
<thead>
<tr>
<th>Year</th>
<th>PELF (Estimate of 1991) G2/M3</th>
<th>PELF (Current Estimate)</th>
<th>PELF per million population (Current Estimate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>95,513</td>
<td>96,750</td>
<td>5,675</td>
</tr>
<tr>
<td>1991</td>
<td>99,780</td>
<td>102,290</td>
<td>5,920</td>
</tr>
<tr>
<td>1992</td>
<td>103,780</td>
<td>107,560</td>
<td>6,150</td>
</tr>
<tr>
<td>1993</td>
<td>106,583</td>
<td>112,290</td>
<td>6,340</td>
</tr>
<tr>
<td>1994</td>
<td>110,535</td>
<td>117,260</td>
<td>6,570</td>
</tr>
<tr>
<td>1995</td>
<td>114,034</td>
<td>122,250</td>
<td>6,770</td>
</tr>
<tr>
<td>1996</td>
<td>117,405</td>
<td>127,480</td>
<td>6,960</td>
</tr>
<tr>
<td>1997</td>
<td>120,569</td>
<td>132,520</td>
<td>7,150</td>
</tr>
<tr>
<td>1998</td>
<td>123,500</td>
<td>137,330</td>
<td>7,480</td>
</tr>
<tr>
<td>1999</td>
<td>126,368</td>
<td>142,270</td>
<td>7,500</td>
</tr>
</tbody>
</table>

The assumed retiring age is 65, on the basis that this is the traditional age of retirement in Australia and in other countries. The resulting PELF is conservatively high in view of the fact that a high proportion of Australians now retire at an earlier age than 65, but assuming this age for all countries enables valid international comparisons to be made. Another factor is that in the model, we assumed that the median age of permanent settler engineers was 28 years of age, while the true median age of immigrant engineers is higher than this. This adds a further conservative bias.
Computed PELF 1990 to 1999
Table 14-14 shows the updated computation of the PELF for the years 1990 to 1999 compared with the previous projection of PELF for the same period, as published Rice and Lloyd (1991). Also shown are ratios of PELF to the Australian population expressed as the number of professional engineers per million.

By 1995 the updated computation of the PELF was 7.2 per cent greater than the previously projected PELF that we regarded as optimistically high, and 10.2 per cent greater than our previous projection for the “most likely”. The explanation lies substantially in the fact that immigration of engineers continued after 1990 at an unprecedentedly high level. The number of permanent settlers categorised as engineers to 1995 was 15,880. Based on long term data, in 1990 we assumed much lower future levels of immigrant engineers in making our projections.

Participation Rates in Engineering
By the end of the five-year period following 1992 our most “optimistic” projection was 12.3 per cent lower than our revised computation for the PELF, and our “most likely” was 16.1 per cent low. After that, the most significant source of differences was our assumption that, in the case of our “most likely” projection for the period 1995-2000, participation rates in professional engineering courses would be 2.5 per cent of the male 22 year-old cohort and 0.4 per cent of the female cohort. These assumed rates were not exceeded until 1995 but after that year they were far too low. Progressively the percentage for males increased until by 1998 it was 3.4 per cent and for females to 0.6 per cent. On current indications these latter percentages are likely to persist for the next three or four years.

The preference of women for certain specialisms in all likelihood will result in the current proportion of females opting to study engineering continuing to persist until such time as electronic and computing, civil and mechanical engineering are regarded by women as attractive as the other specialisms currently favoured.

The average annual rate of growth of the PELF in the period 1989 to 1999 was 4.4 per cent. During the early years of the decade the peak rate of growth was 5.7 per cent per annum. These rates were significantly higher than those resulting from our most optimistic projection in our earlier study in 1991, when we projected 3.2 and 4.2 per cent per annum respectively. As noted, the differences in the estimates of the PELF and growth rates, in part, are a consequence of the very high level of immigration of engineers in the period 1989 to 1999. Our most optimistic assumption was a gross immigration rate of 1,500 engineers, whereas the average figure was 2,330. While the rate of permanent departure of engineers was somewhat higher than we had assumed, this effect did little to counterbalance the unprecedented level of immigration. The net effect was that the total net immigration was over 6,400 in excess of the level assumed in our most optimistic projection. It is noteworthy that in the last five years net immigration of engineers has stabilised at an average of a little under 1,200 per annum.

A relatively insignificant further factor contributing to the change from our projections of annual Australian graduations in engineering was the fact that the age cohorts of 22 year-olds were a little larger than assumed in our projections. The data on which we based our projections were derived from projections by the Australian Bureau of Statistics of the Australian population. These were somewhat lower than the actual levels in the period 1990 - 1999.

A report published by a government agency (Department of Employment, Education, Training and Youth Affairs,1998) provided an interesting comparison with our revised estimates of the PELF. Table 4 of that report indicated that in 1996 there were 106,000 persons with university qualifications in engineering under the age of 65. This estimate was derived by the Department from an ABS publication. Our revised computation for the PELF for that year is 127,480, therefore the ABS estimate was 16.8 per cent less than ours.

The ABS estimate for the Australian PELF is likely to be incorrect because of the nature of the ABS Census question regarding professional qualifications. The question sought the respondent’s highest qualification, and many professional engineers, including those with professional diplomas, possess postgraduate qualifications in fields other than engineering. The results of a survey conducted by APESMA indicate that it is likely that 16.8 per cent of engineers possessed such additional qualifications in 1996. The close correspondence between our revised computation of the PELF and the ABS figure, as adjusted for the discrepancy identified, is a confirmation of our approach to computation of the Australian PELF.
Projected Number of Engineers in Australia
In Rice and Lloyd (1991) we projected the growth of the PELF up to 2010. As in the case of our revised computations for the PELF in the 1990s, we have found that we underestimated the future number of professional engineers. Our revised projections of the PELF for the period 2000-2010 is shown in Table 14-15, where it is indicated that the rate of increase of the PELF will decrease steadily. By 2010 the rate of annual increase is likely to be about 1.8 per cent per annum: a considerable reduction from the peak levels of the early 1990s.

Even more striking is the reduction in the rate of growth of engineer density - the number of engineers per million population. We estimate that the current rate of growth of this parameter is about 2.1 per cent per annum. By 2010 the estimated rate of growth of engineer density will decline to less than 1 % per annum. The indications are that, unless there is a marked increase in the number of completions at bachelor degree level in the latter part of the next decade the rate of growth of engineer density will then tend to zero.

Table 14-15
Estimated Professional Engineering Labour Force: 2000 - 2010

<table>
<thead>
<tr>
<th>Year</th>
<th>Estimate of PELF (1)</th>
<th>Engineer Density (2) (per million population)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>147,100</td>
<td>7,430</td>
</tr>
<tr>
<td>2001</td>
<td>152,100</td>
<td>7,590</td>
</tr>
<tr>
<td>2002</td>
<td>157,200</td>
<td>7,750</td>
</tr>
<tr>
<td>2003</td>
<td>162,100</td>
<td>7,890</td>
</tr>
<tr>
<td>2004</td>
<td>166,800</td>
<td>8,000</td>
</tr>
<tr>
<td>2005</td>
<td>171,400</td>
<td>8,170</td>
</tr>
<tr>
<td>2006</td>
<td>175,900</td>
<td>8,270</td>
</tr>
<tr>
<td>2007</td>
<td>180,200</td>
<td>8,380</td>
</tr>
<tr>
<td>2008</td>
<td>184,600</td>
<td>8,490</td>
</tr>
<tr>
<td>2009</td>
<td>188,900</td>
<td>8,590</td>
</tr>
<tr>
<td>2010</td>
<td>192,300</td>
<td>8,660</td>
</tr>
</tbody>
</table>

Notes: 1. Computations rounded to nearest hundred.
2. Engineer density is the number of persons per million population.

Methodology for Projections
The estimation of the projections of the PELF use a similar methodology to that described above, but assumptions have to be made of engineering graduations, net immigration and deaths. For future engineering graduations, between 1999 and 2003 the annual number of new graduates is projected by the application of past course completion rates for male and female engineering students to the number of commencing students up to 1999 in Table 14-2. From 2004 to 2010 two extrapolations of the annual numbers of engineering graduates are considered.

The first is based on the assumption that the proportions of the relevant male and female age cohorts that completed first degrees in professional engineering, continued to be the same as those that had applied in recent years. The second ‘optimistic’ projection is based on greater proportions of both males and females completing degrees in engineering, by applying an arbitrary factor to the levels of recent years. The factor chosen was 1.3.

The implication of is that 4.6 per cent of the male age cohort and 0.9 per cent of the female age cohort would be assumed to complete engineering degrees. Because this implies a 30 per cent increase in engineering educational infrastructure and staffing, such an increase could not take place in one year, so the estimates phase in the increase in a linear fashion between 2004 and 2010.

Projections of pre-age-65 deaths and of retirements used the same assumptions outlined above. The annual numbers of immigrant and emigrant engineers were assumed to be consistent with recent experience. The assumption that emigration of Australian engineers will continue at or about the same level as applied in recent years is likely to be conservative. Data for the last few years indicate that numbers of immigrant engineers have stabilised. Consequently, we have assumed that this level of migration will persist. This too may be a conservative assumption, as there are indications that some of the Asian ‘donor’ nations are becoming averse to the loss of talent.
Conclusions

The last decade of the 20th Century saw significant change for the professional engineering population in Australia, and change can be expected to continue in the first decade of the 21st Century. The PELF in 2000 was approximately 147,000 engineers, and by 2010 it is likely to be a little over 190,000.

Participation rates and commencements in professional engineering education by both males and females have increased significantly. In the decade of the 1990s the annual number of engineering graduates increased by more than 75 per cent, and immigration continued to be a significant input to the PELF. Engineering in Australia reflected the globalised world: from 1988/89 to 1998/99 more than 26,000 engineers arrived in Australia as permanent settlers. At the same time the number of Australian engineers departing permanently for overseas increased markedly. During the period some 6,000 engineers did so. The departing engineers are likely to be those with internationally marketable capabilities, therefore the real loss is greater than the numbers would indicate.

The decade saw greater involvement of women in professional engineering courses at undergraduate and postgraduate levels. The representation of women in PELF has increased, but present indications are that the proportion will be asymptotic to about 15 per cent in the long term. Australian women prefer some engineering disciplines over others, notably chemical, materials and environmental engineering. If the representation of women in Australian engineering courses were to double without a simultaneous improvement in the popularity of the engineering specialisms that women tend to avoid, the majority of graduates in chemical, materials and environmental engineering would be women, while mechanical, civil and electrical, electronic and computer engineering would continue to be almost exclusively male engineering domains. Any campaign for increased representation of women in the engineering profession should be directed to achieving a balanced commencement pattern across the major specialisms.

There has been a steady increase in the proportion of women bachelor degree candidates commencing doctoral studies in engineering: in 1998 the proportion was over 23 per cent. Therefore it seems likely that in the longer term the proportion of engineering academics will be higher than the proportion of women in the engineering profession, a situation likely to provide profound benefits to engineering education and the profession itself.

The size of the PELF is likely to exhibit continued growth in the first decade of the 21st Century, although the rapid growth of the 1990s is not likely to be repeated. By 2010 the rate of growth of the profession will decline to less than 2 per cent per annum. It is likely that this decline will continue.
Chapter 15
Professionalism in Engineering

By Brian E Lloyd

Introduction

Whither are we tending?

This chapter examines the sociological assumptions underlying engineering as a profession. Concepts of professionalisation, identity and ideals that have motivated professional performance originated during the Industrial Revolution. Change in the 1990s called into question the relevance of traditional models of professionalism. The changed paradigm of engineering at the end of the 20th Century bring the conclusion that engineers now have only a tenuous claim to belonging to a profession as commonly defined. If community reliance upon professional attitudes is to continue to be realistic, new insights are needed into the way professionalised occupations are defined and organised. Abraham Lincoln left advice for this circumstance: ‘If we could first know where we are and whither we are tending, we would be better able to judge what to do and how to do it’.

In Chapter 6 we saw that optimisation of the complex engineering industry system could not rest with any one element. In a situation of fuzziness at the edges of roles of occupational groups, systematic occupational terminology and generic role definition remain essential in effective approaches to the organisation of engineering work and the education that underpins it. Engineering education must continue to promote unambiguous occupational status through coupling between courses, qualifications, work role definition and occupational titles. But will that be enough to ensure the survival of engineering as a professional occupation? This chapter mainly is about engineers, but much of it also applies to engineering technologists, the new professional group that came into being in the 1990s.

Changing Professional Models and Value Systems

The history of engineering in Australia includes fine examples of the inculcation of professional ideals among students and graduate engineers. Until recent decades the engineering schools could rely upon reinforcement of a professional culture through the membership of IEAust and mentorship of new graduates in the workplace by IEAust members. The traditional model of professionalisation of occupations was based upon such expectations, but in the midst of the social and economic change in the 1990s the model underwent significant change. As engineering passes into its 3rd century as a civilian occupation, fundamental and pervasive change has overtaken the way engineering is practiced and organised. Changes came amid societal shifts not confined to Australia. To retain relevance in the 21st century, the approaches of the professional bodies and the design and delivery of engineering education must be informed by an understanding of the nature and extent of change in the organisation and practice of engineering, and in the professional model of engineering. The simple definition of a profession has been:

- A Profession is an occupation based upon a high-level knowledge base that delineates the occupation, work that is intellectual and varied, and a voluntary professional body applying a code of conduct.

The act of 'profession' means declaration of beliefs or intentions, denoting personal responsibility and accountability. From another viewpoint, professionalisation is a form of control over an occupation, in which professional bodies are responsible to their members and to the community to hallmark those competent to practice through grades of membership, and for assurance of adherence to the ethical code of conduct. These values permeated Phases 1 and 2 of engineering, up to 1979. Previous chapters show that the one issue that preoccupied many engineers for over a century was confusion about their occupational identity, and even though they were unable to protect their identity fully, the engineering profession fitted the model. In the changed professional paradigm of Phase 3 of engineering, since 1980 occupational identity has been eroded, as has the claim for professionalisation for engineering. (Phases, see Figure 1-1.)

In this chapter we consider the value systems underlying the concept of professionalism: how professional people define themselves, and how Australian engineering measures up to the traditional model. Chapter 17 reviews the realities of engineering employment, and examines new directions for the organisation of engineering work.
Social Organisation of Occupations

From the beginning of the 19th Century, the three broad phases in professionalisation of occupations were: definition through functional differentiation, institutionalised autonomy following community acceptance as fulfilling a valid social function, and evolution of traits identified with professionalisation. The ideals of professionalism were important shared values. The traits of a professional person acquired in intellectual formation in a body of knowledge, and professional formation through induction into practices and shared values, are considered at length in Lloyd (1991) and summarised as:

- Theoretical knowledge and skills from education, and practice competencies from experiential development.
- Continuing refinement of the knowledge and skills, and lateral extension of practice competencies.
- Organisation through a professional body, and adherence to a professional code of conduct.
- Altruistic service to the profession and the community.

A modern profession may be defined as: an occupation administered by a professional body, with qualified practitioners developing, applying and continuously refreshing complex knowledge and skills of social or commercial value, with commitment to self-determination, service ideals, ethics and interprofessional cooperation.

During the Industrial Revolution cognitive standardisation of branches of engineering evolved as the basis for credentialed professionalisation, initially in civil, mechanical and electrical engineering embodied in the Institutions of Civil, Mechanical and Electrical Engineers in Britain and parallel bodies in the United States. Such developments provided occupational control and identity, and professional competence was hallmarked by membership. The early professional bodies provided the framework for pupilship training and adequacy of intellectual formation.

The knowledge base that delineated the professional occupation created mystification because what the profession did was beyond the comprehension of those not initiated through formation and practice. The resulting cultural differentiation and mystification remain deep for engineers because for most there is no direct client-practitioner relationship as in medicine and law. Cultural differentiation and mystification place a profession beyond direct intervention by the community, therefore professionalisation involves social distance and economic dependence, and autonomy for the profession in taking responsibility for standards and performance.

In an entrepreneurial work ethic, where the objective is accumulation of capital, values concerning the work carried out are extrinsic to the work itself. In contrast, the innate commitment to creative self-expression among professional people engenders a self-belief that their work has intrinsic value, and motivates altruistic service and vocational duty that run deeper than mere compliance with standards or drives for preferment or economic reward. The service ethic enables professions such as medicine, law and accounting to retain a detachment from economic production and to maintain high status, even though large groups of practitioners are within corporate systems. Engineers have had to strive to retain ideals of social obligation while, in the main, their work has been embedded in the economic production systems. Their status gains authoritative legitimacy from their occupational expertise.

The traditional internal view of professional bodies is that membership implies personal and public accountability within an institutionalised form of control providing confidence in competent and ethical performance. But there is a diversity of external attitudes among social and economic analysts, from acceptance of self-definition and autonomy of professions, to scepticism and even outright hostility to the very idea. Some labour market economists impute monopolistic motivations to professional organisations, and ignore their altruistic values. In fact, both economic and idealistic dimensions, together with psychological rewards from vocational satisfaction, contribute to the motivations to which professional people respond. There is a social as well as economic reward in effective professional practice and career advancement within a hierarchy of prestige in the professional body, as well as in the employing organisation. There seems to be no place for such ideas in the ideologies of labour market economics.

Practice Paradigms in Engineering

Do the ideals of professionalism belong to a past age? If the organisation of engineering work is undergoing a paradigm shift, do values in professionalism transcend such change? We have seen that in the first two decades of the 20th Century engineers felt entitled to better pay and status, and were dissatisfied with lack of delineation from unqualified people calling themselves 'engineers'. The IEAust was formed to pursue an entitlement to a level of reward consonant with enhanced status for real engineers in
the community.\textsuperscript{1} During the 1930s many engineers sought to pursue an ideal of \textit{contribution}, but the realists understood that engineers had little chance of achieving significant community leadership because they lacked recognition of professional status. Status depended upon level of reward. In seeking enhanced rewards, \textit{entitlement} was the main motivator, but evidence showed that the \textit{contribution} ideal remained a prime motivator. During Phases 1 and 2 to 1979, the paradigm of engineering practice exhibited certainty of values, complementarity of community, professional and government objectives, little external interference in the work engineers undertook, employee status for most, mainly in the public sector, assured employment and initial development for new graduates, and careers leading to management in hierarchical organisations. Diploma engineers relied upon membership of IEAust for professional recognition, even though that had little meaning in many areas of employment. The traditional paradigm is summarised in Table 15-1.

\begin{table}[h]
\centering
\small
\begin{tabular}{ |l|l| }
\hline
\textbf{Traditional Paradigm} & \textbf{Changed Paradigm} \\
\textbf{Practice Environment} & \\
60\% in public sector, provision of services. & Public sector employment down to about 17\%. \\
Certainty of community & Government privatisation, at the expense of service. \\
& Government interference, non-engineer managers \\
Little external interference in work of engineers. & Less employer and colleague support. \\
Support from colleagues, eg: checking work. & Less training, individual responsibility for CPD. \\
& In-built professional development & CPD. \\
\hline
\textbf{Employment} & \\
Employee status for most engineers; commitment & Uncertain and contingent employment does not offer initial \\
& & professional development. Most organisations except \\
& & consulting offices outsource engineering services, \\
& & reduced experience in design. Fewer career opportunities \\
& & in management. Leadership without authority. Many study \\
& & MBAs for survival skills and escape into general \\
& & managerial roles. Emphasis on individual performance in \\
& & tough employment environments. \\
Training in engineering design in the large design & \\
offices in public utilities and departments. Most & \\
careers lead to management. Loss of expertise in & \\
engineering as a mid-career norm. Little management & \\
expertise in unsophisticated environments. & \\
& \\
\hline
\textbf{Status and Reward} & \\
High proportion of PELF in IEAust. & IEAust membership in decline. \\
Reasonable pay for engineers in salaried & Reasonable reward levels, but continuity of income at risk \\
employment. Enhanced meaning and legal status & in contingent employment. Identity of 'engineer' being \\
for Professional Engineer as defined by IEAust & subsumed as 'professionals', regarded as 'clever \\
qualifications. Little misuse of 'engineer'. Well & workers'. IEAust authority decreasing, as employers \\
defined position classification for engineers. & disregard IEAust recognition. \\
Recognition of para-professional qualifications, & \\
occupational identity & New professional category of Engineering Technologist. \\
& & Misapplication of 'engineer' to para-professionals. \\
& \\
\end{tabular}
\caption{Paradigms of Engineering Practice: Traditional and Current}
\end{table}

The Professional Engineers Award of 1961 added to the practice paradigm: enhanced meaning for \textit{Professional Engineer}, legal authority for the qualifying function of IEAust, defined responsibility levels associated with higher pay, and development of para-professional occupations with qualifications, identity and career structures.

The paradigm shift in engineering practice began in the 1980s. In the 1990s engineers found themselves in situations of frequent change and uncertainty in employment, drastic decline in public sector employment, and for most a shift in emphasis from service to entrepreneurial business. Change brought an acute decline in opportunities for new graduate professional development. Elimination of much middle-management and de-engineering reduced opportunities in engineering-specific management.\textsuperscript{2} The new practice paradigm includes a likelihood of whole careers in technical practice amid the challenges of ever-changing technologies and work roles.

The economic rationalism that destroyed the old professional paradigm fostered individualised competition and loss of focus on the public good. At the same time, ideologies of labour market economists scorned professional values as a veneer covering greed and self-interest, blind to a view that productivity and innovation are derived not only from competence, but also from a work environment based upon human values, appropriate rewards for talent and effort, and vocational satisfaction within an ideal of ethical service. Ideologies about 'efficiency' and 'competition' threatened public good through dismantling professional values. These shifts in the professional paradigm were accompanied by drastic reduction of allegiance to IEAust.
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Chartered and Registered Status
In Chapter 6 the IEAust membership structure was described as a matrix providing Chartered status for engineer, technologist and para-professional members. The IEAust also operates two national registers, the National Professional Engineers Register (NPER) and the National Engineering Technologists Register (NETR). Fully developed procedures apply for professional engineers, and most attention is paid to that category, but issues concerning registration of technologists also are considered. During the 1990s criteria for Chartered Professional Engineer status needed to be updated. The traditional criteria summarised in Figure 15-1 were fashioned during the era of strong public sector support for initial professional formation of graduates in traditional engineering design and construction.

More flexible criteria were required to cater for the employment spectrum from large firms providing structured professional development, to small enterprises where professional supervision was absent. In 1993 new criteria were defined in Standards and Routes to Australian Recognition (SARTAR). Candidates presented an Engineering Practice Report and undertook a Professional Interview to satisfy the National Competency Standards for Professional Engineers, Stage 2. Three routes illustrated in Figure 15-2 were:

(i) **Route 1**: 3-year Structured Development Program.
(ii) **Route 2**: Supervised Experience, minimum 3.5 years.
(iii) **Route 3**: Acquired Professional Experience, minimum 4 years, for other engineers.

The 1993 criteria for CPEng, as in the simpler criteria applied since 1920, were pitched at qualification as an engineer plus 3 or 4 years experience, in a systematic alignment of Member of IEAust (MIEAust), Chartered status, Registration, and Experienced Engineer in the Professional Engineers Awards. The alignment denoted knowledge, skills, attitudes and values derived from educational attainment and intellectual capability, and accountability for competent ethical performance. Competency-based assessment was a key factor in achieving reciprocal recognition agreements at Chartered level with engineering bodies in several other countries, allowing Australian engineers for the first time to engage with Asian clients on an equal footing with their British counterparts. The new criteria also gave substance to the NPER. However, in 1998 changes were made to disconnect MIEAust from Chartered and Registered status:

- Admission to MIEAust remains graduation plus 3 or 4 years experience, but is not competency tested. MIEAust retains the nexus with the APESMA award provision for Experienced Engineer.
- The new Standards (NCSPE, 1998) require experience virtually impossible to acquire in 3 or 4 years initial professional development, placing Chartered and Registered status well beyond the previous level of attainment of MIEAust and Experienced Engineer. Applicants for CPEng present an Engineering Practice Report (EPR) and undergo an Interview. Retention of CPEng is conditional upon CPD, and lost if CPD is found wanting.
- The NCSPE (1998) include a compulsory requirement for several years experience in every aspect of engineering design, ignoring the new paradigm under which engineering enterprises outsource most design, and taking no account of the much diminished public sector training opportunities in design. A late amendment coupled 'planning' with design, but the detail is about *traditional* design.
- Electives in NCSPE (1998) do not emphasise technical expertise. Project and environmental management are featured, but construction and maintenance engineering are obfuscated within 'engineering operations'.
These decisions by IEAust disrupted the coordinated system that had been built up carefully to coordinate professional status with employment and industrial relations. Disconnecting competency assessment from MIEAust, and raising the bar for compliance with the competency demands placed CPEng out of reach for most young engineers. Some are likely to seek the status of MIEAust but many will be daunted by the demands of the process leading to CPEng, because making an application would entail a high risk of rejection. It seems likely that more graduate engineers than ever will avoid the issue and not join IEAust, but simply rely on their degree and their CV. The new inhibiting criteria could jeopardise the future viability of IEAust.

Registered Professional Engineers

In 1989, with APESMA and the Association of Consulting Engineers Australia, IEAust established the NPER to provide the basis for registration under legislation or regulations or standards requiring engineering expertise for defined functions. By 2000 only a small portion of practice was covered, but some 10,000 engineers found it desirable to demonstrate registered standing. The Register lists practitioners with a commitment to ethical practice and maintenance of competence. In an environment of government deregulation, it provides assurance that registrants are subject to discipline if they fail to observe their CPD obligations. Employers thus are able to take NPER as a third-party certification of their professional engineering staff. The NPER is open to every engineer eligible to become a CPEng and a Member of one of the IEAust Colleges of Engineers, and to non-members having equivalent qualifications and experience. Features of Registration are:

- Postnominal: Members: CPEng(Reg) or (Discipline). Non-members: PEng(Reg) or (Discipline).
- Criteria: as for CPEng, or assessed as equivalent, in specific areas of expertise.
- Adherence to the Code of Ethics and IEAust disciplinary provisions.
- Conditional upon maintained CPD and lost on non-compliance.

Registration is renewed annually. Applicants are obliged to undertake 150 weighted hours of CPD over rolling periods of three years, and certify that they have spent a total of at least one year during the previous three in independent practice or working as an employee under general direction, or enrolled in a postgraduate course relevant to their registration category or categories. Self-certification is subject to random audit. Under the new registration regime, engineers with registered status are likely to represent a small and diminishing elite within the body of professional engineers.

Registered Engineering Technologists

Engineering Technologists are defined in terms of 3-year degrees, and upgrading opportunities to BTech for para-professionals became realistically accessible through off-campus degree programs (Chapter 12). Despite such access, and the requirements of the Competency Standards, in the late 1990s IEAust offered a competency-based pathway to NETR and CEngT for 2-year qualified para-professionals on the basis of assessed experience, but without explicit requirements for an assessed knowledge base equivalent to the benchmark 3-year qualification. The value of NETR thus was undermined as real Engineering Technologists viewed the 'easy' experiential pathway as an assault upon their identity as 3-year qualified professionals. Harmony between Technologists and para-professionals was seriously disturbed. The availability of the 'easy' pathway dissuaded many para-professionals from studies in articulated education. The IEAust approach again disrupted the work-force system that had been developed so carefully, and ignored societal values in which 3-year qualifications are professional and 2-year qualifications are para-professional. A systems view indicates the need for a National Register for engineering para-professionals to reinforce their special Chartered status. The IEAust approach was a gross distortion of the value of NETR, and it leads to the following discussion.

Qualification-based Occupational Identity

As discussed above credentialled occupational identity began for engineering at the beginning of the 19th Century as professionalism of occupations evolved in cognitive standardisation of fields of endeavour. Later, educational qualifications, supplemented by induction into practice, reinforced occupational identity. Members of a profession became bound by common qualifications, occupational titles, professional value systems, and agreed role definitions. The coupling of qualifications to occupational identity became an essential of professionalisation. While in Chapter 6 watertight boxes are not advocated for restricting the work of occupational categories, when the work-force is considered in systems terms there must be a logical consonance between education, work roles, work values and occupational titles, pro-
Providing unambiguous identities based upon qualifications. Some overlaps at the margins between the work of occupations is inevitable, but ambiguous occupational identity raises false expectations. Qualification-based occupational identity is at the core of the orderly organisation of the spectrum of engineering work.

Occupational groups have fuzzy edges that change with technological and social evolution. Chapters 2, 3 and 6 provide many demonstrations of the extent of expansion of the spectrum of engineering work. The total spectrum changed and expanded as para-professional and technician occupations were identified from the 1960s, as illustrated in Figure 15-3. Before 1980, 3-year engineering diplomas were professional engineering qualifications. By the 1990s the range, depth and nature of work had changed to accommodate a different 3-year qualification for engineering technologists, with education directed to that specific work segment. A strategic view must allow BTech graduates clarity and pride in their occupational identity. Separate recognition of para-professionals is essential if they are to have pride in their occupational identity. Figure 15-3 depicts how engineers and technologists overlap in functions, while Chapter 6 shows how they are differentiated. Members of each occupation take pride in identity flowing from qualifications. Every occupation has value within a system of interdependencies requiring harmony and co-operation. The expression 'engineering team' epitomises the systems view. Therefore qualifications-based occupational identity is essential for an effective work force system. Occupational identity is considered further, after considering the changing model of professionalisation of occupations.

Models of Professionalisation

Monopoly in Professionalisation

Professional people engage in intellectual work requiring formation in a knowledge and skill base, and are expected to abide by ethical values in the interests of employers, clients and the community. The traditional model envisages qualifications for admission to a professional body that defines and administers a code of conduct. The early purpose of professionalisation was to provide confidence in competent and honest work, personal integrity and accountability, and a service motivation. These values inspired professional work and the satisfaction gained from it.

Before formal education evolved in the 19th and early 20th Centuries, the knowledge base of each profession was passed on through the professional body that provided recognition. The community conceded monopoly advantages in an implied social contract: if the profession did not exercise adequate control, it risked loss of autonomy and government regulation. The traditional model, as summarised in Table 15-2, envisaged membership as the criterion for entry to, and conduct of, professional practice. For engineering until the mid-20th century, that model was reasonably effective inasmuch as the engineering institutions covered the great majority of engineers. The IEAust exercised a de facto monopoly over professional recognition.

The major changes in the model have been loss of monopoly over both admission to practice and over the knowledge base. In the professional model of engineering in Australia, responsibility is shared between IEAust and APESMA, whose memberships at the end of the 20th Century together represent only about one third of the Professional Engineering Labour Force (PELF). Some 8 out of 10 working age engineers living in Australia are not members of IEAust at any point in time. A foundation stone of the traditional model therefore is missing. A larger proportion of engineers are members at some time, but allow their membership to lapse. This is the major problem of IEAust.
Table 15-2  
Models of Professionalisation of Occupations for Engineers

<table>
<thead>
<tr>
<th>Traditional Professional Model</th>
<th>Current Model for Engineers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Professional body:</td>
<td></td>
</tr>
<tr>
<td>- Membership of professional body as exclusive criterion for admission to practice.</td>
<td>- Degree as criterion for admission to practice. Less than 25% of working age engineers are members of IEAust.</td>
</tr>
<tr>
<td>- Examination qualifications of professional body the sole criterion for admission to professional practice.</td>
<td>- Degrees QA accredited by IEAust, or assessed for recognition. No compulsion to join IEAust.</td>
</tr>
<tr>
<td>- Professional body passes on knowledge base.</td>
<td>- Knowledge base held by engineering schools.</td>
</tr>
<tr>
<td>- Professional body defines and administers code of conduct</td>
<td>- Code of Ethics applicable only to members of IEAust and APESMA, and a few others on NPER.</td>
</tr>
<tr>
<td>- Professional body responsible for ensuring competent and honest performance</td>
<td>- No control over non-members or other engineers not on NPER, that is, some 70% of practitioners.</td>
</tr>
<tr>
<td>Professional shared values:</td>
<td></td>
</tr>
<tr>
<td>- Practitioners inspired by service to employers, clients, and the community.</td>
<td>- Contracts determine relationships with employer or client. Consideration of the community relevant only to practitioners who are subject to the Code of Ethics.</td>
</tr>
<tr>
<td>- Practitioners expect high quality intellectual work providing vocational satisfaction. General expectation of ethical values, altruism and service motivation, integrity and accountability.</td>
<td>- IEAust encourages altruistic values and personal integrity among about 25% of practitioners. Approaches to professional life for non-members depend only upon personal values.</td>
</tr>
<tr>
<td>Social contract with the community:</td>
<td></td>
</tr>
<tr>
<td>- Community concedes advantages to members of the professional body, in consideration of:</td>
<td>- No exclusivity conceded to members of IEAust. Small advantages to some who are registered on NPER.</td>
</tr>
<tr>
<td>- A commitment by members to ethical behaviour and contribution to community good, before self-interest.</td>
<td>- Control of standards for admission and ethics applies only to about 25% of practitioners.</td>
</tr>
<tr>
<td>- Professional body exercises adequate control of standards and behaviour of all practitioners.</td>
<td>- Autonomy of IEAust not an issue for great majority professional engineering practice or employment.</td>
</tr>
<tr>
<td>- Inadequate control by the professional body risks loss of autonomy through government regulation.</td>
<td>- Economic rationalism promotes non-professional attitudes and destroys community side of contract.</td>
</tr>
</tbody>
</table>

**Participation in IEAust**

In the 1920s IEAust membership peaked at nearly 70 per cent of the PELF. Figure 15-4 shows a steady decline in participation.\(^5\) The exception to the general trend in the late 1950s and early 1960s was associated with the Professional Engineers Case, reflecting the appreciation by engineers that their professional bodies were actively pursuing the individual interests of members. Reasons for the general long term reduction of interest in IEAust are many, some of which are:

- Motivations to join are twofold: the status benefit, and altruistic obligations to contribute to the profession.
- The first is attenuated by indifference of many employers, and the cult of individualism among graduates whose degree and a CV are seen by them to fulfil all needs for recognition.
- The second motivator is attenuated through increasing materialism. Decreased participation in trade unions, down from 50 per cent in 1980 to 25 per cent in 2000, is similar indication of the sociological phenomenon of decline in propensity to join collective groups.
- There is a decreased need for IEAust certification since 1980, before which diplomates valued recognition. While it is IEAust that safeguards qualification and practice standards, and maintains international recognition, IEAust makes little effort to convey the obligation to support those functions through membership.
- Some academics take the self-centred view that IEAust is not relevant to *their* personal academic needs, and they advise students to join foreign institutions rather than meeting obligations to the Profession of Engineering in Australia.
- Graduates who lack mentoring may believe APESMA and IEAust are in competition.
- IEAust projects an image of exclusivity rather than inclusivity for professional engineers, while adopting ambiguous attitudes to technologists and para-professionals, even acceding the descriptor 'professional' to para-professionals in expressions such as 'continuing professional development', and is indifferent to misuse of the title 'engineer'.
- In the absence of vigorous promotion by IEAust, many employers fail to link qualifications to accu-
rate occupational descriptors, and there is ignorance and apathy to regarding Chartered status among members, non-members and employers.

- Many graduate engineers never work under the guidance of an IEAust member, nor receive advice or are in contact with referees to certify professional engineering experience, so interest in joining IEAust lapses.

- To the outside world IEAust is powerful, and significant in the international profession. Politicians and bureaucrats take notice of IEAust, which achieves much for the profession. But it all happens behind doors that remain closed. IEAust projects an image to members and potential members of inactivity.

- The IEAust undertakes no visible activities in promoting the title ‘engineer’, let alone positive promotion of correct usage of ‘engineer’ as the professional title in engineering.

- Communication with IEAust members is minimal. For 25 years the magazine *Engineers Australia* made little effort to inform members about professional issues, policies or developments, nor to engender a professional spirit, nor to engage in promotion of ethical or community obligations. There were a few signs of improvement in 2000, but the damage of omission has been done for generations of indifferent engineers.

The trends evident in Figure 15-4 indicate that the membership reach of IEAust into the PELF is likely to decrease further. Another aspect of the trend is seen in Figure 15-5. It cannot be claimed, therefore, that *professionalisation* of the body of professional engineers is a reality, especially as the professional body neither actively seeks to foster professionalism nor ethical consciousness even among the minority who are members, let alone among the great majority of professional engineers who are not members.

**Monopoly over the Knowledge Base**

The IEAust cannot exercise monopoly over the knowledge base of engineering. Education is administered by universities, and the IEAust exercises a quality assurance function through accreditation. Entry to professional engineering practice is open to all with the qualifications and competencies required, and the decision to employ a person as an engineer lies with employers.

However, governments continue to concede authority to IEAust in terms of accreditation of education and competency requirements, together with assessment of the qualifications of foreign-qualified engineers. But the community concedes no advantages to those who take up membership of IEAust. Voluntary membership is open to all with the required qualifications. However, for most working age engineers living in Australia, the degree has replaced IEAust membership as the criterion for occupational and professional recognition.

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**Figure 15-4 Engineers in PELF Participating in IEAust 1919-1999 and Projected to 2010**

**Figure 15-5 PELF and IEAust Members: 1980-2010**
professional recognition. No monopoly can exist.

Control of Ethical Practice
A variant of the traditional monopoly exists in registered professions such as medicine and law, where State registration boards exercise control over the whole profession and are heavily influenced by members of the relevant professional body. In that situation voluntary professional bodies can exercise significant influence over admission, ethics and behaviour, even if only a minority of the profession were members. The public practice of accounting goes further: membership of the professional body is the condition for many aspects of practice.

For engineering, in earlier times the traditional model may have been effective for control of ethical behaviour, inasmuch as the IEAust covered the great majority of persons in consulting practice, and until the middle of the 20th Century ethical practice was not an important issue for employee engineers. Towards the end of the 20th Century the need for ethical behaviour in business, and for social and environmental responsibility, became issues for all engineers. In that context, IEAust holds itself out as the guardian of community interest through oversight of ethical behaviour, and APESMA co-operates in respect of engineer members of the Association not belonging to IEAust. However, while sanctions may be applied, and expulsion or reprimand has an impact upon reputation and income potential for an individual, the reach of the professional bodies cannot extend beyond their memberships. Ethical regulation of the whole of professional engineering practice cannot be exercised because:

1. Although registration on NPER requires IEAust recognition and adherence to the Code of Ethics, the requirement for registration does not yet extend far into areas of practice.
2. Engineer and technologist members of IEAust and APESMA are bound by the same Code, but these bodies cannot regulate practice beyond their members and the few non-members who register on NPER or NETR.
3. Awareness of ethical obligations even among members is low. Printed copies of the Code are not even distributed to members as a matter of course. There is neither the mechanism nor the will to raise awareness of ethical obligations among non-members.

Where does this leave the social contract between the profession and the community? Under the contract the professional bodies are conceded autonomy over standards and ethical conduct, provided that control is exercised responsibly in the interests of the community. But professional bodies in these largely unregistered occupations cannot exercise control over the ethical behaviour of non-members who constitute the great majority of practitioners. Thus, community expectations are misplaced. For rationalist ideologues, the objective of elimination of a professional ethos in engineering has been achieved.

Some consequences of the new engineering paradigm are quoted in Appendix A.

Ethics and Occupational Identity
Use of the Title 'Engineer'
Much heat was generated from time to time during the 20th Century concerning misuse of 'engineer'. Attitudes ranged from passionate distress to indifferent acceptance of a lost cause. As discussed in Chapter 16, misuse began in the mid-19th Century when British metal tradesmen began to call themselves 'engineers'. During the 20th Century engineers in English-speaking countries endured more of this kind of confusion than most other professionals. The problem continues in Anglo-American cultures where inappropriately qualified individuals attempt to sell their services as qualified engineers, and companies employing such people purport to provide professional engineering services.

At the end of the 20th Century qualification-based occupational identity came under a new challenge, as role designations such as 'professional' and 'manager' replaced 'engineer' and 'chief engineer'. The converse of para-professionals claiming the title 'engineer' intensified the problem. While such trends result in role confusion in the work-force system, this chapter is concerned with the associated professional and ethical issues. So that the point will not be lost in a confused conventional wisdom, consider the following typology:

(a) Colloquial: The vernacular occasionally applies 'engineer' to tradespeople, train drivers in USA, mechanics who repair domestic appliances, and the like. Such usage perpetuates public confusion about identity and roles of professional engineers, but it does not involve deliberate intent to deceive and professional or ethical issues are not present. This chapter is not concerned with colloquial misuse even though it harms the professional image.
(b) **Marginal:** Non-professional usage in statutory or semi-official contexts, as in 'Licensed Aircraft Maintenance Engineer', 'Marine Engineer', 'sales engineer', 'Certified Microsoft Engineer', 'computer engineer', and the like, is an annoyance in perpetuating public confusion, but it too is a lost cause and does not deceive informed 'clients'. Professional or ethical issues are marginal, but a worthwhile professional body would make concerted efforts to mitigate the nuisance to professional identity. For example, in Europe titles such as 'Certified Microsoft Engineer' are prohibited.

(c) **Deceitful:** The 1990s saw an increase in the misapplication of 'engineer' as an identifier where 'engineer' normally means 'professional engineer'. Examples occur in some large consulting engineering firms, local government bodies, industrial companies, and para-professionals offering consulting or contracting services. When a person with a para-professional or technologist qualification, or no qualifications at all, is held out to informed or uninformed clients as an 'engineer', fraudulent deception is likely to be present. If public health and safety depend upon the professional competencies of such a person, there is a risk of criminal deception. While there may be legal redress in particular cases, in most there is no societal sanction against these kinds of occupational misrepresentation.

This chapter is concerned with deceitful usage. A professional body is expected to make efforts to eliminate it, for protection of public health and safety and the good name of the profession and its members. If the offending person was a para-professional or technologist member of IEAust, and hence subject to the Code of Ethics, there is an obligation on IEAust to take punitive action. Professional members are ethically obliged to contribute to elimination of the practice and never to be complicit in it.

A worthwhile professional body also would make efforts to mitigate this offence among non-members and their employers. Such actions in the public interest could never be held to be anti-competitive, even though confronting the ideology of labour substitution theory.

(d) **Unprofessional:** The late 1990s brought pressures on IEAust to provide for competency-assessed occupational articulation from para-professional to technologist, and from technologist to engineer. There can be no objection to assessment and certification of prior studies and experiential learning in a competency-based assessment, provided *that definition by function* is not the sole criterion. Evaluation also must ensure possession of the normal knowledge and skills essential to the competencies of the higher occupation.

Without an expert and thorough assessment of the knowledge base of the applicant against the yardstick of the normal qualification benchmark, no such certification ever should be countenanced. Any professional body prepared to certify professional engineer or engineering technologist status on the basis of *definition by function*, without rigorous evaluation of the associated knowledge base, would jeopardise public confidence and place public health and safety at risk. A professional body is expected to protect professional qualifications, and public health and safety, against inadequately educated pretenders.

**Trends in Engineering Identity**

Misrepresentation of the generic title 'engineer' in the media not only harms professional status in the community, but also the effectiveness of real engineers as educated and creative professional people. Their annoyance relates mainly to misuse in the media, but there is surprising apathy when it comes to corrective action.

In 1971 there was a push within the Executive of IEAust to import the then British occupational descriptor 'technician engineer' as a title for engineering para-professionals. The push demonstrated a surprisingly cavalier attitude to the occupational identity that had been won a decade before at high cost in the Professional Engineers Case. The move raised alarm in APEA: it was unbelievable that IEAust was prepared to institutionalise misuse of 'engineer' that would have developed into deceitful misrepresentation. After much argument the title 'Engineering Associate' was adopted and the threat to professional occupational identity was averted.

There remained a few engineering para-professionals who hankered for official blessing as 'engineers'. In the 1990s the title was conferred upon some of them by employers. While these practices do harm to the status and reputation of professional engineers, the greater underlying ethical anxiety concerning occupational misrepresentation has to be concerned with the potential for jeopardising the welfare, health and safety of the community. This kind of occupational illegitimacy could not exist without
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the apathy or connivance of engineers in positions of authority and influence. Nor could it exist without the indifference of the IEAust.

The trend for submerging the occupational identity of 'engineer' in a generality of 'professionals', and an increased misapplication of 'engineer' to para-professionals and technologists, could cause people with professional engineering qualifications to believe that identity as an 'engineer' may be detrimental to their career ambitions. Will engineering graduates seek some higher form of life beyond that of mere 'engineer'?

A major blow was struck for the forces of evil in 1999, after a century of disquiet among Australian engineers concerning misappropriation of 'engineer'. A decision by the IEAust leadership implicitly accepted that anyone can use the title. The circumstances were as follows. When IEAust put the case to the membership in the early 1990s to admit engineering technologists and engineering para-professionals, there was considerable opposition: one third of Chartered Professional Engineers voted against the plan on the grounds of the risk of impairing the professional identity of engineers. The safeguard was to amend the Code of Ethics to cover all categories of membership, with a guideline: Members ....'shall acknowledge that the terms 'professional engineer', 'engineer' or 'member' of the engineering profession are used to describe only those persons eligible to be Graduate or Corporate Members of the Institution. Members who are not so eligible shall not indicate that they possess such qualifications.'

In 1999, without any consultation with the membership, IEAust changed the clause to read: Members 'should acknowledge that the terms 'professional engineer', or 'member' of the engineering profession . . .' By deleting 'engineer' the prohibition against misuse was lifted. The members of IEAust were not even informed of the change, let alone appraised of its effect. The cavalier approach of IEAust leaders in overturning a century of history was breathtaking! The membership, the partners in the Code of Ethics, APESMA and ACEA, and the consequences of this action, all were completely ignored!

When 'reputable' organisations hold out an unqualified person as an 'engineer', the normal interpretation of this term is 'professional engineer'. A disclaimer would be unlikely. Misleading intent is more likely than naive ignorance. In such cases, the Code of Ethics applies to IEAust members regardless of the changed guidelines: if non-engineer members hold themselves out, or are held out to be 'engineers', they are in breach of the Code by:

- inducing clients or members of the community to believe them to be professional engineers;
- acting dishonestly towards the community, including clients, employers and colleagues;
- compromising welfare, health and safety through misleading others on qualifications and competencies; and
- risking that others may conclude their opinions are based upon competencies of a professional engineer.

Of course, IEAust cannot enforce the Code in relation to fraudulent misrepresentation unless membership of the Institution were claimed. Nevertheless, if IEAust were serious about protecting the professional reputation of its engineer members, and the public good, it would expect all members to abide by the Code, and ethical obligations would extend to protection of the public from detrimental effects flowing from any misrepresentation. It is starkly clear that collusion, or turning a blind eye, by any member of IEAust in this kind of misrepresentation would constitute a breach of the Code. However, the indifference of IEAust to this issue is manifest, not only in the change in the ethical guidelines, but also in its own information systems. In a service to members called Job Scan, positions advertised in the press are placed before members regardless of the nature of the job labelled as 'engineer'. A random sampling of Job Scan for 31 July 1999 revealed:

- Engineer: Trade qualifications or Associate Diploma desirable.
- Technical Engineer: Novell CNA or Microsoft MCP qualification.
- Engineer Junior: Higher School Certificate or other certificate required.
- Engineer Customer Support: technical qualifications, work as technical assistant.

The professional identity of engineers comes under serious threat when, by its passivity, IEAust condones such inane distortions of professional identity in its own publication. In undermining the occupational identity of the professional people it purports to represent, IEAust can hardly expect to merit the allegiance of those yet to join it. The Institution effectively has renounced responsibility to safeguard the occupational identity of professional engineers.
Conclusions
The model of professionalisation of engineering, vigorously pursued for a century, has become meaningless. The traditional model has undergone drastic change as community values and economic ideologies changed. The aspiration of engineering to be a profession has lost substance, especially in the face of indifference to the central issue of occupational identity. The great majority of professional engineers have rejected IEAust, which has made no serious effort to gain their allegiance, nor to redefine itself in a form relevant to their needs.

As seen in Chapter 5, as recently as 1985 the profession was greatly affronted by labour market economists accusing IEAust of infringing the tenets of labour market ideologies. The accusers ignored the dependencies between community good and professional standards and ethics. At that time IEAust was confident of community faith in its role as a professional body, and responded in robust terms. In 2000 IEAust still acted upon the same the belief, but how could community faith be justified in the face of declining membership participation that is still falling?

The occupational identity of the engineer, problematic throughout the 20th Century but largely protected in dominant public sector employment, came under challenge in the 1990s in the new privatised and deregulated world. Debasement of ‘engineer’ came from employers misrepresenting unqualified people, and from para-professionals to claiming to be ‘engineers’. When IEAust lifted the ethical prohibition on its non-engineer members calling themselves 'engineers', in 1999 it abdicated the obligation to defend the community against fraudulent deception. Such erosion of ethical values could not occur without connivance of engineers. No committed professional person nor professional body could be a party to such situations.

Changed community values are reflected in the economic and social context of engineering. With governments espousing and enforcing competition and labour market deregulation, competition between individuals and self-interest take precedence over professional values. It should not be surprising that allegiance to the profession and to IEAust became a secondary issue for the majority of engineers. Nor should it be surprising if self-interest ultimately displaces community interest in an occupation that has become deprofessionalised. What is surprising is that there has been no effort within IEAust to face up to the new world. The wider contemporary context for professional people has been summarised by Simon Longstaff:

if belonging to a profession is to be taken seriously . . . . it requires a fundamental commitment to act in a spirit of public service. Indeed this what distinguishes a member of a profession from people in the marketplace. While most people are officially allowed to pursue self-interest, members of a profession are supposed to put the interests of the community, their clients or patients, first. In the days before we sacrificed commonsense to the ideology of competition and ‘economic correctness’, society used to ensure that the professions enjoyed some reasonable benefits in return for their commitment. However, this old social contract has been broken.

The experience of IEAust in the 1990s in attempting to integrate para-professional categories into membership would seem to be a failure because professionals in leadership roles failed to understand or be interested in para-professional issues, and the para-professional members expected to achieve falsely inflated occupational recognition through IEAust. With mismanagement of essential issues on both sides, there now appears to be no effective place for para-professionals within the professional organisation of engineering, but there remains a need for communication and continuing efforts for harmonisation of objectives and policies.

Professional bodies are confronted by new realities. What will their shape be in the middle of the 21st Century? Has the tribal construct of professionalisation had its day? No linear projection based upon the 200 years of history could come anywhere near the mark in addressing these questions. The only certainty is that the traditional professional model is gone. The need is for an inclusive model with a member-centred approach attuned to the total work-force system. The future seems likely to hold the fading of IEAust into an elite club of elderly engineers, while the realities of administration of the profession take a different form as:

• Accreditation: a quality assurance function by the engineering schools, under a nominal umbrella of IEAust.
• Recognition of foreign qualifications and international reciprocity for recognition: a matter for employers.
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- Certification of stages in career development (as in IEAust grades): redundant.
- Certification of competency: needs determined by enterprises or government agencies, perhaps through a reconstituted NPER independent of IEAust.
- Conferences, and CPD provisions arranged by professional interest societies.
- Ethical practice: requirement determined and administered within general business ethics.
- New forms of association catering for the employment, remuneration and social needs of increasing numbers of casualised professional employees (as considered in Chapter 17.)

These conclusions might imply an ongoing validity for some kind of attenuated and much changed professional model. Much depends upon developments overseas, and the continued international standing of IEAust in the light of its fading influence in Australia. Such projections presuppose the continued existence of an identifiable professionalised occupation called 'engineering'. That too must be in question in any realistic view of long-term future trends.

Notes to Chapter 15

1 Lloyd and Vines (1995), Beder (1998), Chapter 2. Beder's social analysis is pertinent but overlooked Lloyd (1991), and her uncritical reference to engineer populations is out of touch with Rice and Lloyd (1990 and 1991). Neither is she au fait with the industrial relations of Australian engineering, having neglected Lloyd and Vines (1995), and she has little regard for history of engineering qualifications.

2 The epitome of this kind of change is the Telstra Corporation, the largest engineering-based organisation in Australia. The classification 'Professional Engineer' has been replaced by 'Professional' as a noun. The CEO in 1999 was a physicist, and the 10 Group General Managing Directors included only 2 engineers. The Board of Directors included not one engineer. Contrast with the history of the organisation (Moyal 1984) is stark.

3 Pre-1999 CPEngs retain the postnominal as long as they remain in IEAust.

4 Accounting, represented by the Institute of Chartered Accountants in particular, is an example of the traditional model, mirrored also by the Australian Society of Certified Practising Accountants: each controls professional status through formalised induction training and examinations under their control, sharing a monopoly over professional recognition that has wide statutory backing.

5 Participation rate is defined as: engineers under age 65 living in Australia and members of IEAust, as a proportion of the PELF. IEAust members overseas, non-engineer members, retired IEAust members and students, are not included. The graph is based upon an analysis of IEAust membership statistics.

6 Lloyd (1991), pp. 171 et seq. Ironically, in Britain at the end of the 20th Century there were complaints from the Incorporated 'Engineers' (erstwhile technician 'engineers') about misuse of their title 'engineer'.

7 The Australian, 22 October 1999, Executive Director of the St James Ethics Centre, writing on an ethical dispute concerning the behaviour of radiologists in their relations with the Federal Government.
Chapter 16
Professional Engineers in the National Economy

By Michael R Rice

Introduction
Confusion about the roles and capabilities of professional engineers is a significant factor limiting the contribution of engineering to the national economy. As discussed in Chapter 15, the occupational identity of engineers in Australia continues to be blurred. On the one hand there are those who continue to believe that engineers are involved in a manual occupation, although this image of the profession may be fading. On the other hand there is a common misapprehension that engineers are principally involved in construction; hence the use of photographs of individuals wearing hard hats to illustrate press articles about engineers. Often such illustrations are irrelevant to the content of the article.

The fact that the activities of engineers, particularly in advanced industrial countries, are related to high technology activities seems to be beyond the comprehension of most journalists and other shapers of opinion. This is well illustrated by dialogue in the Australian film The Dish in which a leading character soliloquises to the effect that the Lunar landing expedition was the greatest scientific feat of the 20th Century. Despite plentiful instances of scientific magazines, including New Scientist, attempting to make it clear that space flight is an engineering achievement, the script writers were still under the delusion that scientists had performed the engineering miracle that space flight represents.

Perhaps because of the widespread Australian misapprehensions as to the nature of engineering in the modern economy, students still gravitate to science studies at a rate that outrrips any other country, while they turn their backs on engineering studies. It is because of this that, while there has been a rapid increase in enrolments in engineering courses in Australia in recent times, the Australian rate of completions of engineering courses does not compare well with advanced industrial countries.

Many Australian economists and political leaders downplay manufacturing and advocate policies that maintain the derivative nature of our technology. They are not concerned about the relatively low rate of graduation of engineers in comparison with advanced industrial nations. However, if Australia sought to raise the level of research and development (R&D) in the manufacturing sector, such that it is comparable with countries such as Sweden, Finland, Korea or Taiwan, it is unlikely that there would be sufficient young research engineers available. Therefore Australia faces the problem of attracting adequate numbers of able young people into professional engineering, in particular into mechanical and electronic engineering and related specialisms pertinent to manufacturing. The issue of the image of the engineer and of the engineering profession is a vital factor in attracting suitably able students to engineering courses. In consequence, rather than being an issue of concern confined to engineers themselves, the image of the engineer is of vital concern to a community that stands to gain from the contributions of engineers to the national economy, or lose from their absence.

International Comparison of Engineering Graduation Rates
The increase in the annual number of persons graduating in engineering in Australia, as discussed in chapter 14, might lead to an optimistic conclusion that Australian engineering graduation rates compare favourably with other countries. Nothing could be further from the truth, as a perusal of Table 16-1 indicates. This table compares the annual number of graduates with first degrees in engineering relative to population for a number of countries, listed in descending order of magnitude.

The most recently available data relate to a period five years ago except in the cases noted. There is no reason to believe that the passage of time since the mid-1990s has resulted in a change in the relative standing of the countries shown, although the magnitudes of the rates of graduation of some of the countries may have increased. Singapore is one such country, where recent enrolment data suggest that within the next few years annual graduations of engineers will achieve a level equivalent to 1,000 per million population - the highest in the world. In comparison, as indicated in Chapter 14, it seems likely that the number of Australian engineering graduates per million population could decline during the decade.
Table 16-1
Number of First Degree Level Engineering Graduates Relative to Population

<table>
<thead>
<tr>
<th>Country</th>
<th>Year</th>
<th>Graduates in engineering relative to population (per million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Korea</td>
<td>1997</td>
<td>898</td>
</tr>
<tr>
<td>Singapore</td>
<td>1998</td>
<td>837</td>
</tr>
<tr>
<td>Japan</td>
<td>1997</td>
<td>816</td>
</tr>
<tr>
<td>Finland</td>
<td>1996</td>
<td>768</td>
</tr>
<tr>
<td>Denmark</td>
<td>1993</td>
<td>650</td>
</tr>
<tr>
<td>Taiwan</td>
<td>1997</td>
<td>601</td>
</tr>
<tr>
<td>Norway</td>
<td>1994</td>
<td>502</td>
</tr>
<tr>
<td>Germany</td>
<td>1997</td>
<td>486</td>
</tr>
<tr>
<td>Belgium</td>
<td>1993</td>
<td>450</td>
</tr>
<tr>
<td>Ireland</td>
<td>1993</td>
<td>435</td>
</tr>
<tr>
<td>Switzerland</td>
<td>1996</td>
<td>435</td>
</tr>
<tr>
<td>Netherlands</td>
<td>1997</td>
<td>430</td>
</tr>
<tr>
<td>Sweden</td>
<td>1996</td>
<td>410</td>
</tr>
<tr>
<td>France</td>
<td>1996</td>
<td>391</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>1997</td>
<td>383</td>
</tr>
<tr>
<td>Israel</td>
<td>1996</td>
<td>311</td>
</tr>
<tr>
<td>Australia</td>
<td>1998</td>
<td>280</td>
</tr>
<tr>
<td>United States</td>
<td>1996</td>
<td>238</td>
</tr>
<tr>
<td>Austria</td>
<td>1997</td>
<td>202</td>
</tr>
<tr>
<td>Italy</td>
<td>1996</td>
<td>189</td>
</tr>
</tbody>
</table>

Sources: Derived from data published in:

Table 16-1 shows that Australia graduates far fewer engineers relative to population than many other industrial countries, a situation that has prevailed for many years. Comparative data were first published in a study undertaken on behalf of the then Association of Professional Engineers, Australia (Rice, 1969). Later studies confirmed that Australia’s comparatively low rate of graduation of engineers had continued (Rice, 1984, 1987, and 1993). If it had not been for the very large number of foreign engineers settling in Australia, the size of the Australian Professional Engineer Labour force (PELF) would compare even more unfavourably with that of other industrial countries. Currently, engineers whose professional qualifications were obtained overseas represent 24 per cent of the Australian PELF.

Australia also performs poorly in the rate of graduations of engineers when compared with other Pacific-rim countries. It is likely that Singapore will graduate over 3,500 engineers annually within three to four years. That number would represent about 75 per cent of the number of graduations in Australia, while the population of Singapore is less than one-sixth of that of Australia.

Australia’s low ranking is likely to persist because the number of engineers graduating in those countries continues to increase while the recent number of commencements in Australia indicate that graduations in Australia are not likely to increase substantially for at least five years.

In the last decade in Singapore the growth in education of engineering education at post-graduate level has been staggering. The number of Singaporeans completing higher degrees in engineering has increased from 126 in 1993 to 891 in 1999. The latter figure does not fall far short of the current number of completion of higher degrees in engineering in Australia, with six times the population. Enrolment data indicate that the rate of graduation of Singaporean engineers with higher degrees will continue to increase. Currently, higher degree enrolments in engineering represent 44 per cent of all higher degree enrolments in Singapore. In contrast, higher degree enrolments in natural, physical and mathematical sciences are less than 7 per cent of total enrolments in that country.

That the ‘Asian tigers’ are concentrating on the expansion of their professional engineering work forces is unquestionable. The same cannot be said of their attitude to the supply of natural scientists. In Singapore’s case, the total number of undergraduate enrolments in the natural sciences is only one-fifth
of the number of undergraduate enrolments in engineering and has increased only 16 per cent in the period 1993 to 1999. In the same period the number of undergraduate enrolments in engineering has increased by nearly 90 per cent. A somewhat similar pattern prevails in post-graduate education. The number of postgraduate enrolment in engineering increased from 1,439 in 1993 to 5,551 in 1999. Consequently, Singapore has more postgraduate students in engineering than Australia. The educational priorities of Singapore are exemplified by the fact that that postgraduate enrolments in the sciences are less than one-sixth of those in engineering. Table 16-2 provides a powerful demonstration of the emphasis on engineering education in many counties other than Australia. It is noteworthy that the dynamic Asian economies are to the forefront of these comparisons. Australia lags badly behind most of the countries in the tabulation.

Table 16-2
Engineering Graduates as a Proportion of all Graduates

<table>
<thead>
<tr>
<th>Country</th>
<th>Engineering graduates as a proportion of all graduates, %</th>
<th>Male engineering graduates as a proportion of all male graduates, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Singapore</td>
<td>28.4</td>
<td>48.1</td>
</tr>
<tr>
<td>Finland</td>
<td>25.1</td>
<td>42.6</td>
</tr>
<tr>
<td>Belgium</td>
<td>22.0</td>
<td>33.0</td>
</tr>
<tr>
<td>Germany</td>
<td>20.6</td>
<td>30.1</td>
</tr>
<tr>
<td>Japan</td>
<td>19.7</td>
<td>27.3</td>
</tr>
<tr>
<td>France</td>
<td>18.7</td>
<td>26.8</td>
</tr>
<tr>
<td>Switzerland</td>
<td>17.9</td>
<td>n.a.</td>
</tr>
<tr>
<td>Taiwan</td>
<td>17.7</td>
<td>24.3</td>
</tr>
<tr>
<td>Netherlands</td>
<td>16.7</td>
<td>22.5</td>
</tr>
<tr>
<td>Korea</td>
<td>16.2</td>
<td>30.5</td>
</tr>
<tr>
<td>Sweden</td>
<td>15.9</td>
<td>27.7</td>
</tr>
<tr>
<td>Denmark</td>
<td>15.2</td>
<td>29.6</td>
</tr>
<tr>
<td>Norway</td>
<td>11.5</td>
<td>30.1</td>
</tr>
<tr>
<td>Ireland</td>
<td>11.3</td>
<td>20.4</td>
</tr>
<tr>
<td>Austria</td>
<td>10.3</td>
<td>16.4</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>9.3</td>
<td>22.3</td>
</tr>
<tr>
<td>Italy</td>
<td>8.7</td>
<td>16.9</td>
</tr>
<tr>
<td>Australia</td>
<td>6.2</td>
<td>12.1</td>
</tr>
<tr>
<td>United States</td>
<td>5.3</td>
<td>5.9</td>
</tr>
</tbody>
</table>

Note: The data for all countries relate to 1994 except for the following countries which are listed together with the year to which the data for each country relates: Australia - 1998; United States and the United Kingdom - 1996; Japan, South Korea, Republic of China (Taiwan), Austria and Switzerland - 1995; Belgium, Denmark, Ireland and the Netherlands - 1993; Singapore - 1999.

Sources: Derived from data published in:

A criticism that might be levelled at the above comparisons is that they merely represent proportions and therefore do not provide a realistic basis for assessing the degree of commitment of the countries in the tabulation to engineering education. Table 16-3 might be of assistance in this regard since it provides data concerning the proportion of the relevant age cohort of males graduating in engineering.

The only conclusion that can be drawn from the table is that Australian males are less inclined to undertake engineering education than their opposite numbers in the other industrial countries with the exception of the United States, Sweden and Italy. In considering the comparison with these countries it should be borne in mind that their education systems provide for second level of engineering education that has not been taken account of in the table. In the United States there is second level of engineering education that produces graduates in engineering technology, a category that has not yet grown significantly in Australia. The four-year BSET graduates in the US, described in Chapter 13, are regarded as
equivalent to engineers by many employers. In addition the United States has been encouraging short term and long term immigration of engineers from Asia and Europe on a large scale.

### Table 16-3

<table>
<thead>
<tr>
<th>Country</th>
<th>Proportion of male age cohort completing a first degree in engineering (per cent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Singapore</td>
<td>10.3</td>
</tr>
<tr>
<td>Finland</td>
<td>9.5</td>
</tr>
<tr>
<td>Japan</td>
<td>8.9</td>
</tr>
<tr>
<td>South Korea</td>
<td>7.1</td>
</tr>
<tr>
<td>Netherlands</td>
<td>7.0</td>
</tr>
<tr>
<td>Norway</td>
<td>5.3</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>5.0</td>
</tr>
<tr>
<td>Ireland</td>
<td>4.0</td>
</tr>
<tr>
<td>Australia</td>
<td>3.7</td>
</tr>
<tr>
<td>United States</td>
<td>3.7</td>
</tr>
<tr>
<td>Sweden</td>
<td>3.0</td>
</tr>
<tr>
<td>Italy</td>
<td>2.1</td>
</tr>
</tbody>
</table>

Note: The data for all countries relate to 1994 except for the following countries which are listed together with the year to which the data for each country relates: Australia - 1998; United States and the United Kingdom - 1996; Japan, South Korea, Republic of China (Taiwan), Austria and Switzerland - 1995; Belgium, Denmark, Ireland and the Netherlands - 1993; Singapore - 1999.

Sources: Derived from data published in:

### Roles of Engineers in the Work Force

#### Occupational Identity of the Engineer

The question of occupational identity is discussed in Chapter 15, and further considered here in a different context. Judging from the references to engineers in the Australian media there are widespread misconceptions as to the roles of engineers in the work force and the nature of the work that engineers undertake. The ‘hard hat’ problem is mentioned above; the reality is that only a very small proportion of engineers wear protective helmets in the course of their work. Another problem is the unfortunate tendency on the part of policy makers and science pressure groups to mask the identity of engineers by the use of ‘technologists’ and ‘researcher’.

The situation is far worse in the British media. Not uncommonly metal tradespeople, technicians and mechanics are described as ‘engineers’ while professional engineers, particularly those engaged in ‘high tech’ are described as ‘scientists’. A notable exception is the British journal New Scientist which scrupulously avoids such misuse of the language in its references to scientists and engineers. Many engineers have complained about a continuing misrepresentation of their title, but the problem persists (see for example, Petroski, 2000, and Laithwaite, 1984), and some engineers even have begun to defend it, as discussed in Chapter 15. Those who refuse to understand the importance of accuracy in description of occupations hold that there is not really a problem, or alternatively, or if it is a problem, to solve it engineers simply have to bend their best efforts to employer or the community benefit, and the problem will fix itself. That kind of gratuitous nonsense would lead to the unwarranted conclusion that engineers have failed to do the job their employers and the community expect of them, since there has been no improvement in this situation over the last two generations. In fact, the problem worsened in the 1990s, as discussed in Chapter 15.

That there is a problem is only too evident from the failure of the Australian community to enjoy the benefits of having an adequate supply of engineers deployed in the activities that form part of their role, by comparison with the countries discussed above. The failure of Australian engineering schools to
enjoy the level of representation evident in the higher education systems of advanced industrial countries is another element of the problem.

**Definition of Research and Development (R&D)**

The definitions employed in this book are consistent with those used by the OECD: Research and experimental development: may be defined as a creative work undertaken on a systematic basis to increase the stock of scientific and technical knowledge and to use this stock of knowledge to devise new applications. Three categories of R&D are distinguished: basic research; applied research; and, experimental development.

- **Basic research** is original investigation undertaken primarily for the advancement of scientific knowledge, without any specific aim or objective.
- **Applied research** is original investigation undertaken in order to gain new scientific and technical knowledge but is directed towards a specific practical aim or objective.
- **Experimental development** is the use of existing knowledge to produce new or substantially improved materials, devices, products, processes, systems or services.

The foregoing definitions clearly imply that product and process development are included in the statistics of R&D activity.

**Roles of Professional Engineers**

What are the normal roles of engineers in advanced industrial economies? This question can best be answered by considering the surveys undertaken by the National Science Foundation of the United States. Normally, that body categorizes engineering and scientific functions in accordance with the classifications shown in the Table 16-4, which relates to the distribution of American engineers between different standardised job functions in all engineering specialisms.

<table>
<thead>
<tr>
<th>Primary work activity</th>
<th>Proportion of engineers (All sectors) (Per cent)</th>
<th>Proportion of engineers (Industry sector) (Per cent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research &amp; development</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Basic research</td>
<td>0.5</td>
<td>0.2</td>
</tr>
<tr>
<td>Applied research</td>
<td>3.7</td>
<td>2.5</td>
</tr>
<tr>
<td>Development</td>
<td><strong>28.4</strong></td>
<td><strong>31.6</strong></td>
</tr>
<tr>
<td>All R&amp;D</td>
<td>32.6</td>
<td>34.3</td>
</tr>
<tr>
<td>Management/ administration</td>
<td>30.2</td>
<td>30.0</td>
</tr>
<tr>
<td>Teaching</td>
<td>2.3</td>
<td>0.4</td>
</tr>
<tr>
<td>Production</td>
<td>17.4</td>
<td>17.3</td>
</tr>
<tr>
<td>Other</td>
<td>17.5</td>
<td>18.0</td>
</tr>
<tr>
<td>Total</td>
<td>100.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>


It is noteworthy that the predominant role of American engineers is the performance of R&D. Production and related functions such as quality control represent work functions of a minority of engineers. In the case of electrical/electronic, chemical and mechanical engineering, the pattern of work activities varies from the overall average. Data from the source document indicates, for example, that 44 per cent of electrical/electronic and mechanical engineers are employed in industry and are engaged in R&D.

Young engineers are more likely to be engaged in R&D than those in the later stages of their professional engineering careers. In the first two years of their employment over 36 per cent of all engineers with bachelor degrees were engaged in R&D (National Science Foundation, 1997). The proportion of mechanical engineers so engaged was as high as 45 per cent.

The proportion of newly-graduated engineers with master degrees engaged in R&D was over 50 per cent, while for mechanical engineers with master degrees the proportion rose to 60 per cent. Because of the predominance of R&D in the functions of engineers in more advanced industrial societies such as the US, it would be short sighted to call for ‘reform’ of Australian engineering education to provide graduates more immediately useful to employers, at the expense of providing them with the more enduring intellectual capabilities. If Australia is to engage seriously in international trade in high technology...
manufactured goods, it is essential that a good proportion of young engineers are endowed with capabilities and competencies comparable with those of the engineers of the nations with which we hope to compete.

In Chapter 1 a historical comparison is made of trends in the distribution of engineering functions of Australian engineers. A different view is presented from data derived from the regular six-monthly salary survey undertaken by the Association of Professional Engineers, Scientists and Managers of Australia (APESMA). In addition to information on salaries, these surveys elicit a certain amount of sociological information about the respondents, and Table 16-5 is based upon averaging the results of the four most recent surveys in 1998 to 2000. Until recently respondents were provided with a definition of R&D that was consistent with that applying in the United States. The differences between this table and Table 1-1 in Chapter 1 arise from differences in the survey samples and the instruments used.

### Table 16-5

<table>
<thead>
<tr>
<th>Primary Work Activities of Australian Engineers</th>
<th>Proportion of engineers (Per cent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research and development</td>
<td>10.5</td>
</tr>
<tr>
<td>Design</td>
<td>14.9</td>
</tr>
<tr>
<td>Management</td>
<td>32.8</td>
</tr>
<tr>
<td>Teaching/training</td>
<td>0.8</td>
</tr>
<tr>
<td>Production</td>
<td>11.5</td>
</tr>
<tr>
<td>Construction supervision</td>
<td>7.4</td>
</tr>
<tr>
<td>Other</td>
<td>22.1</td>
</tr>
<tr>
<td>Total</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Even though some of the categorisations of work functions in the APESMA survey are not consistent with those employed by the National Science Foundation, it is not difficult to observe that Australian engineers are not as heavily engaged in the performance of R&D as American engineers. Table 1-1 confirms that the level of involvement of Australian engineers in R&D activities has not varied to a very great extent over a long period. Until recently the proportion of Australian engineers so engaged was about one third of the proportion that prevails in the United States, while the proportion of engineers involved in management and administration is very much the same in both countries.

The difference in the proportions of engineers engaged in R&D arises from the low level of R&D undertaken by Australian manufacturing industry. Few OECD countries or other industrial countries commit such a small proportion of GDP to R&D in the manufacturing sector (Rice, 1992). Little has changed since 1992 except that, following an increase to a peak level four years ago, manufacturing R&D, expressed as a percentage of GDP, has now returned to the relatively low level of 1992-23.

The low involvement of engineers in R&D in Australia may also be a consequence of the structure of industry in this country, as well as the attitudes of an Australian managerial class having little comprehension of engineering and the benefits of industry-based R&D. Another factor may be the high level of foreign ownership of Australian industry. Many foreign-owned Australian companies have no interest in export development of Australian-designed goods, nor in undertaking research and development in Australia, when they can import designs from parent companies.

### R&D Personnel in the United States

The fact that American engineers are so massively engaged in R&D would be contrary to the suppositions of many in the Australian community. These assumptions may be a consequence of the low representation of Australian engineers in the R&D function. It may also be a consequence of the cultural heritage from Britain in which there is such a poor perception of the nature of engineering.

A sidelight on the foregoing analyses is that it is possible to compare US engineers with scientists. Science graduates employed in scientific work represent only a small proportion of all science graduates. An even smaller proportion of science graduates employed in science-related jobs industry were engaged in R&D than is the case for engineers. This is a significant finding in the light of the widespread assumption that science and R&D are synonymous.

Analysis of US data published by the NSF indicates that 27.3 per cent of American natural scientists and computer specialists, actually engaged in scientific occupations, were involved in the perform-
ance of R&D. Confining the analysis to the industrial sector indicates that 24.5 per cent of such personnel were engaged in the performance of R&D. It may come as a surprise that in the US, engineers are more likely to be researchers than science and information technology specialists. However, many scientists employed in science-related occupations in American industry are likely to be engaged in functions such as routine analysis and production control as well as management. Information technologists are likely to be engaged in functions associated with routine data processing rather than in R&D.

As for engineers, some categories of scientific professionals are more likely to be engaged in research and development than others. For example, the NSF report indicates that 43 per cent of physical scientists employed in American industry were researchers. However, the number of physical scientists employed in American industry was much smaller than the number of engineers: the NSF data shows that only 14 per cent of researchers in US manufacturing industry were natural scientists. Physicists, who constituted less than 2 per cent of all engineers and scientists in American industry, represented only a little over one per cent of researchers in that sector.

Therefore the common misconception that R&D is the province of scientists is not correct. In manufacturing industry the involvement of engineers in R&D is even greater than it is in industry as a whole (Rice, 1994). In the United States up to 83 per cent of researchers in the manufacturing sector are engineers. In electrical equipment, electronics, communications equipment and transport equipment manufacturing, over 95 per cent of researchers are engineers. In drawing these conclusions, the aero-space and missile industries were excluded in order to provide a more valid comparison with economies that do not include a substantial aircraft and missile industry component. This industry sector has an especially high proportion of engineers engaged in R&D.

The foregoing analyses are supported historically by the results of the 1982 US postcensal survey of engineers and scientists (NSF, 1984). This analysis indicates that, nationally, 67 per cent of American researchers were engineers, and that physical scientists constituted less than 10 per cent of the total number of researchers. Focusing solely on the industrial sector the analysis shows that engineers made up 78 per cent of researchers. The proportion of researchers who were engineers would have been even greater in the predominant manufacturing sub-sector of industry, but the data do not permit further disaggregation.

If the analyses for the US manufacturing sector were to exclude industries such as food, chemicals, basic materials and non-metallic products, the proportion of researchers who were engineers would increase to about 92 per cent.

R&D Personnel in Japan and Taiwan

Analysis of data relating to the Japanese manufacturing sector (Science and Technology Agency, 1992 and Rice 1994) suggested that 62 per cent of researchers in the Japanese manufacturing sector were engineers. However, Rice indicates this figure is likely to be an underestimate. At the time that the data were collected by the Japanese government agency, the number of science graduates in Japan’s manufacturing sector was less than 100,000, while the number of ‘science’ researchers was roughly of this magnitude. It would follow from this that virtually all science specialists in the Japanese manufacturing sector would be engaged in R&D. This is very unlikely because, as in the case of engineers, a significant proportion of science graduates would be engaged in functions other than research. In any case the analysis of Japanese manufacturing sector excludes industries such as food, chemicals, basic materials and non-metallic products, and about 80 per cent of researchers in the ‘engineering-based’ industries were identified as engineers.

A similar study of the pattern in the Republic of China (Taiwan), (National Science Council, 1996) shows that in 1994, as in previous years, over 90 per cent of researchers in the manufacturing sector were engineers. There was also a high concentration of engineering researchers in the other sectors of the Taiwanese economy, such that there were six engineering researchers for each science researcher. The pattern in higher education reflected the emphasis on engineering research in Taiwan. In 1994, engineering researchers in the higher education sector represented 33.6 per cent of the total number of researchers in that sector. In the same year engineering researchers in Australian universities made up less than 17.5 per cent of researchers in higher education.

An examination of the government sectors of Japan and Taiwan yields a somewhat similar story. In 1994 over 50 per cent of researchers in the Taiwanese government sector were engineering research-
ers; less than 23 per cent of Australian government sector researchers fall into that category. However, because of deficiencies in the Australian research classification used until 1999 the data cannot be determined precisely. Engineering activity is overestimated and science activity is underestimated. As a result of advice provided to IEAust and thereby passed on to the ABS, the research classification has been amended to correct deficiencies. It may be presumed that future surveys of Australian R&D activity will provide more realistic estimates of the levels of R&D expenditure and personnel in the different fields of research. It seems likely that future data for Australia will indicate an even greater relative imbalance between engineering and science in the distribution of government and university R&D expenditure and personnel than the preceding comparisons indicate. Further information is given in Appendix B.

Implications for Australia’s R&D Capability

If Australia’s manufacturing sector expenditure on R&D were to be increased to the average level of expenditure in the OECD, it is likely that there would be difficulty in providing the human resources to undertake that level of activity. Assuming the catch-up in R&D were to take place by 2010, there would then be too few engineers in the appropriate age group and with the appropriate education and skills to support the required level of expenditure (Rice, 1994). This factor is usually ignored by policy makers and their advisers, who assume that there is a limitless supply of skills in the community. However, their are clear limits on the future availability of engineers in general and specialist engineers in particular. This is a potentially critical problem that deserves further analysis.

To a considerable extent, the R&D capability of the manufacturing sector is limited by the available supply of young engineers qualified in the specialisations identified above and who are not required for the performance of other engineering work in the manufacturing or other sectors. R&D is a labour intensive activity predominantly undertaken by electronic, communication, electrical and mechanical engineers in the earlier stages of their professional careers. It is significant that the median age of respondents to APESMA surveys who indicated that they were engaged in R&D was 31 years of age, and only 20 per cent were over 38. Three considerations on this subject appear to have been ignored:

- A significant proportion of all the engineers currently engaged in R&D will have moved on to other activities after about 10 years.
- Because of continuing economic growth, the real average level of expenditure on manufacturing R&D in the OECD countries will have increased by a significant amount. Therefore to some extent each country is forced to run to keep up with the others. The human resource requirement is affected by this factor as much as any other.
- It is implicit in the absence of concern for human resource problems, that up to now Australia had to rely upon immigration of engineers at a relatively high level. However, in view of the fact that the median age of immigrant engineers is about 33 and that many would take a year or two to adapt to Australian engineering practice and culture, this source of new engineers might not be of much assistance in overcoming the human resource deficit in potential engineering research.

Qualifications of Engineering Researchers

Analysis of US data on the levels of qualification of American researchers in 1982 explodes the myth that R&D is the province only of those who possess postgraduate degrees (NSF 1984). Across all sectors, 16 per cent of engineering and science researchers held doctoral degrees, 25 per cent held master degrees and 49 per cent held bachelor degrees or other qualifications. There was a wide divergence between the patterns of qualifications of those in basic research and other researchers. Similarly the pattern of qualifications of engineering researchers differed substantially from those of scientific researchers. This was also true of researchers in industry as against other researchers.

Those engaged in basic research were most likely to hold advanced degrees. For engineering and science researchers as a whole, 68 per cent of those working in basic research held doctoral level qualifications and another 17 per cent possessed master degrees. Only 15 per cent of researchers involved in basic research did not hold postgraduate degrees. The emphasis on higher degrees in basic research was even more pronounced in scientific fields, where over 71 per cent held doctoral degrees. In contrast, 27 per cent of engineering researchers undertaking basic research were qualified to doctoral level, another 23 per cent held master degrees, while the remaining 50 per cent possessed bachelor degrees or other qualifications.
In the industry sector 4 per cent of all researchers held doctoral degrees, 25 per cent possessed master degrees and 69 per cent held other qualifications. When engineering researchers in the industry sector are considered in isolation only 3 per cent were qualified to doctoral level, 21 per cent held master degrees and over 75 per cent were qualified to first degree level only. Only 15 per cent of industrial researchers were natural scientists or computer specialists. Over 54 per cent of researchers in science-related fields in industry held postgraduate degrees including 12 per cent who held doctoral degrees.

Because at the time of the survey the great majority of American industrial R&D was undertaken in the manufacturing sector, it is reasonable to assume that the pattern of qualifications for the industry sector as a whole was representative of that prevailing in the manufacturing industries. The rest were engineers. Thus the true picture of industrial research is that it is a function mainly undertaken by engineers who were qualified to bachelor degree level.

Qualifications of Australian Engineers
For some time many Australian engineers have sought further qualifications in their discipline beyond the bachelor degree level. The results of the APESMA surveys provide one measure of the increasing number and proportion of engineers who have acquired postgraduate degrees in engineering.

At the beginning of the last decade 19.4 per cent of respondents to the APESMA surveys reported that they possessed postgraduate qualifications in engineering, including graduate diplomas, master degrees and doctoral degrees. Master and doctoral degrees had been obtained by 12.3 per cent of the respondents. These proportions held up to the middle years of the decade, but by the end of the decade there was a perceptible increase in the proportion of the respondents who had acquired further professional engineering qualifications. By that time 21.1 per cent of the respondents reported that they had successfully completed postgraduate studies and 13.6 per cent possessed master or doctoral degrees in engineering.

These percentage changes may not appear to be very large, but as they occurred over a period of rapid growth in the number of engineers, they are very significant in numerical terms. Assuming that the respondents are representative of the entire engineering profession and applying the above proportions to the total membership of the profession, one could conclude that over 7,000 engineers had acquired postgraduate qualifications in a six-year period and not far short of 5,000 had completed master or doctoral degrees in engineering.

Data published by DEETYA indicate that 6,287 non-overseas students completed master or doctoral degrees in engineering, surveying and metallurgy in the period 1992 to 1998. Assuming that 8 per cent of these degrees were not in engineering and bearing in mind the losses to the profession from the brain drain plus deaths and retirements, the estimates based on the APESMA survey data do not appear to be wildly optimistic. There is no reason to expect that the increase in the proportion of engineers with post-graduate qualifications in engineering will not continue. As indicated in Chapter 14, the annual number of commencements in higher degrees in engineering remains at a high level, if not quite so high as it was in the early 1990s.

Engineers as Managers
Apart from activities in R&D, engineers have a significant roles in managerial functions. A recent review of the characteristics of American engineers (Ellis, 1997) demonstrates that not only are a high proportion of engineers employed in management but that 17 per cent of engineering graduates are top or middle managers. The same study pointed out that one quarter of American middle managers are engineers.

Another investigation reviewed the representation of engineers and certain other professionals in the ranks of chief executives in the leading companies of Canada and the United States (Whittaker, 1991). The study found that in the top 1,000 companies nearly 47 per cent of chief executive officers (CEOs) possessed degrees in business-related disciplines, 26 per cent were qualified in engineering and 10 per cent held degrees in fields related to science. Another analysis quoted by Whittaker found that, of the Fortune 500 companies, 33 per cent of CEOs were qualified in business studies, 24 per cent held engineering degrees and 6 per cent were qualified in some field of science. In the case of the top 200 Canadian companies, 22 per cent were led by business graduates, another 22 by engineering graduates and nearly 10 per cent of the CEOs were science graduates. An analysis of the educational backgrounds of
the CEOs of the top 995 companies reported in an American business magazine (*Business Week, 1989*) produced the results summarised in Table 16-6 (Rice, 1998).

Combining the data for the 28.6 per cent possessing business-related qualifications (business, finance and marketing), the representation of those with such qualifications was of the same order as that for those with engineering qualifications. Those who initially qualified in accounting and finance constituted 4.3 per cent of the total. This was unexpected in view of the received wisdom that those with financial backgrounds are destined for top management. It will be no surprise that a large number of banking, insurance and other financially-oriented institutions were included among the ‘top 1,000 corporations’. Table 16-6 also includes a further analysis that segregating the CEOs of the manufacturing companies, and shows the proportion whose initial qualification was in engineering was nearly 40 per cent, while graduates from business and economics disciplines were not as well represented as in the corporate sector as a whole.

Table 16-6

<table>
<thead>
<tr>
<th>Field of initial qualification</th>
<th>All Companies</th>
<th>Manufacturing Companies</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Proportion of CEOs</td>
<td>Proportion of CEOs</td>
</tr>
<tr>
<td></td>
<td>(Per cent)</td>
<td>(Per cent)</td>
</tr>
<tr>
<td>Engineering</td>
<td>27.3</td>
<td>39.6</td>
</tr>
<tr>
<td>Business/administration</td>
<td>23.0</td>
<td>20.1</td>
</tr>
<tr>
<td>Economics</td>
<td>11.8</td>
<td>8.7</td>
</tr>
<tr>
<td>Humanities</td>
<td>6.6</td>
<td>4.6</td>
</tr>
<tr>
<td>Natural Science/mathematics</td>
<td>5.5</td>
<td>6.8</td>
</tr>
<tr>
<td>Law</td>
<td>4.4</td>
<td>1.2</td>
</tr>
<tr>
<td>Finance/accounting</td>
<td>4.3</td>
<td>4.3</td>
</tr>
<tr>
<td>Marketing</td>
<td>1.3</td>
<td>1.0</td>
</tr>
<tr>
<td>Applied science</td>
<td>1.0</td>
<td>0.4</td>
</tr>
<tr>
<td>Other fields</td>
<td>1.7</td>
<td>5.9</td>
</tr>
<tr>
<td>No degree</td>
<td>13.1</td>
<td>7.7</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

Note: 1. Applied science includes pharmacy and agricultural science.
2. The data relate only to those CEOs whose qualifications were ascertainable. About one-sixth of the CEOs possessed university qualifications that could not be identified.

The proportion of engineer CEOs varied from one industry group to another. More than 70 per cent of chief executives in the semiconductor and electrical products industries were engineers. In contrast only 33 per cent of CEOs in the pharmaceutical industries had initially qualified in engineering. Over 40 per cent of the top managers of computer and computer components industries held engineering qualifications.

A comparison of the average profitability of the companies in 10 separate industry groups in the manufacturing sector indicated that those companies led by CEOs with an engineering background produced better results in seven out of the 10 cases. A separate analysis of the utilities represented in the ‘Top 1,000’ showed that, of 85 chief executives whose primary university qualifications could be determined, nearly 52 per cent held an engineering degree. Graduates in business studies or accounting made up 22 per cent and those with economics qualifications represented another 9 per cent. Less than 3 per cent of CEOs in the utilities sector had no university qualifications.

It is well known that many of the past leaders of industry in America were engineers, and that much of the basis on which modern management practice was founded was established by engineers. The foregoing analyses simply confirms that American industrial prosperity remained largely in the hands of professional engineering leadership. Therefore, in the globalised world of at the beginning of the 21st century, it is difficult to understand why the myth of the managerial incapacity of engineers as a professional group continues to exist in Australia.
Professional Engineers with Non-engineering Qualifications

Engineers are becoming a very highly qualified occupational group. In recent years there has been an increasing tendency for engineers to undertake postgraduate studies in fields other than engineering. The APESMA salary surveys cast light on the trends in the proportion of engineers completing qualifications in non-engineering fields of study. In the late 1980s approximately 9 per cent of respondents indicated that they possessed additional qualifications in fields other than engineering, including about 3 per cent with master or doctoral degrees. A significant number had completed graduate diplomas or master degrees in business studies. By the late 1990s the proportion of respondents with postgraduate qualifications in other fields than engineering had increased to 22 per cent, and those with master or doctoral degrees had increased to 8 per cent. This upward trend is likely to continue since the proportion of respondents who are undertaking post-graduate studies is increasing. As noted in Chapter 12, the MBA (Technology Management) presented by APESMA has been a major contributor to this new situation.

If one accepts that the proportions of respondents who possess postgraduate qualifications is representative of the profession as a whole, approximately 43 per cent of professional engineers possess post-graduate qualifications in engineering or other fields. This conclusion is predicated on there being no overlap between those with engineering post-graduate qualifications and those with other postgraduate qualifications. No doubt some overlap has occurred, but it is doubtful if this would much reduce the estimated proportion of those with postgraduate qualifications.

In addition to postgraduate qualifications in other fields, another 8 per cent of respondents possess bachelor degrees in fields unrelated to engineering. Thus, in total about 50 per cent of respondents possess qualifications in engineering or other fields in addition to their initial engineering qualifications. It is doubtful if any other professional group is so well qualified.

Deficiencies in Census Data

Because of the relatively large number of engineers with post-graduate degrees in fields other than engineering, it is difficult to obtain reliable data on engineers because the Australian Census question regarding educational qualifications asks respondents to state their highest qualification. For obvious reasons, this leads to an error in the Census estimate of the number of persons possessing engineering qualifications. Such a miscount may not have been significant in the early 1980s when fewer than 8 per cent of engineers possessed postgraduate qualifications in non-engineering fields. However, by 1996 Census the error had increased to about 15 per cent. By the time of the next Census in 2001, over 20 per cent of those with engineering qualifications will not be included in the Census as possessing professional engineering qualifications. Unless the ABS changes the nature of the census question, it is likely that the magnitude of the error in the estimate of the number of persons with engineering qualifications will become larger.

The problem has been brought to the attention of ABS, as the organisation responsible for the Census, but the question remains unaltered. In view of the increasing magnitude of the under counting, the issue was again raised during the preparatory stage of the 2001 Census but to no avail. As a result, about 30,000 persons with professional engineering qualifications will not be counted as persons possessing professional engineering qualifications during the Census. In consequence the most reliable computations of the PELF are those provided in this book and in Rice and Lloyd (1991).

Image of the Engineering Profession

Comments on the misuse of the title ‘engineer’ are made in Chapter 15 and elsewhere in this book. We note above the blurring of understanding about what professional engineers can do as a factor in their ability to make effective contributions to the national economy. Many engineers wince when they hear a call over an airport PA system for an ‘engineer’ to undertake work on aircraft. The source of this irritation is the designation ‘Licensed Aircraft Maintenance Engineer’, introduced by the British Government after World War I. The term first appeared in legislation in 1921, before which ‘aircraft mechanic’ was the term normally employed in Britain both in the civil industry and the military forces. This legislated misuse of ‘engineer’, also applied in Australia, is only one example of the problem in many English-speaking countries.

Professional engineers have always been irritated by the misuse of their title. The situation improved following the clarification in occupational identity provided by the Professional Engineers award in 1961. Misuse of ‘engineer’ decreased until the late 1990s, when an increase in the problem became
evident. While some engineers complained, a new phenomenon arose when some other engineers defended a wider application of the title. (See letters in issues of *Engineers Australia* in 1999 and 2000.) As noted in Chapter 15, even IEAust adopted a *laissez faire* attitude in respect of ethical obligations of non-engineer members.

The former Australasian Society of Engineers and the Amalgamated Engineering Union exacerbated the problem, but they have disappeared into the Australian Manufacturing Workers Union. Perhaps it has become less usual to see a newspaper advertisement for a ‘maintenance engineer’ or ‘diesel engineer’, once common, and now usually replaced by ‘maintenance fitter’ and ‘diesel mechanic’. But in the UK ‘lift engineers’ continue to repair lifts and ‘engineers’ install TV antennas. The modern trend is more insidious: para-professionals with diplomas are beginning to misappropriate the title ‘engineer’, a title never before applied to them. Because they can now become Chartered members of IEAust, when such members misrepresent themselves as ‘engineers’, the potential for misrepresentation as professional engineers is evident.

**Origin of Misuse of ‘Engineer’**

When and why did the error originate? Misuse of the engineer title can be traced to the mid-19th Century. Chamber's Encyclopaedia states that before the 1820’s the term ‘engineer’ was not applied to the ‘workmen now known as ‘engineers’ . . . . Such people ‘were commonly called mechanics, a general term covering many crafts.’ Formation of the Society of Civil Engineers in 1771 was the precursor of the formation of the Institution of Civil Engineers in 1818, to provide recognition for members of the new profession of civil engineers, as distinct from ‘military engineers’. Military engineering had existed as a professional occupation for many centuries. There seems to have been little confusion in Britain before 1851, by which time the Institution of Civil Engineers, and the Institution of Mechanical Engineers founded in 1847, had firmly established the professional nature of the role of the civilian engineer.

In January 1851 a small number of craft associations undertook the ‘Grand Amalgamation’ to create a new national union intended to cover all the metal trades. The title of the new organisation included the names of a number of the trades that it was hoped would be involved in the amalgamation. Thus, the new union became ‘The Amalgamated Society of Engineers, Machinists, Smiths, Millwrights, and Pattern Makers’, although at the outset the term ‘Operative Engineer’ was included rather than ‘Engineer’. The ‘operative engineers’ whose abbreviated designation by chance was listed at the beginning of the new Society’s name were members of one very small trade union with a membership of much fewer than 700 tradesmen. That union appears to have been unique in using the term ‘engineer’ in its title.

The membership of The Amalgamated Society was almost entirely made up of members of the Journeymen Steam Engine and Machine Makers’ Friendly Society and, at its inauguration included no ‘operative engineers’ in its ranks, since the relevant union did not wish to be included in the amalgamation. A short time later it changed its attitude. Thus, at the time of the initial ‘amalgamation’, an amalgamation in name only, there was only one union represented in the new union, ‘The Old Mechanics’. Usage caused the title of the new union to be abbreviated to ‘The Amalgamated Society of Engineers’ as a matter of convenience. Before long this came to be the accepted title. The real engineers did not object, and so the rot set in.

If the sequence of occupational designations in the original name of the amalgamated union had not been as it was, the abbreviated name of the Amalgamated Society would have been different. However, as a result of an accidental sequence of events, by the 1880’s the term ‘engineer’ became applied to artisans as well as to professionals. This appears to be the reason that the term ‘engineer’ has become to be misused in the UK and some of its former colonies, and to a lesser extent in the United States. The ‘British malady’ has plagued the Profession of Engineering ever since, to the serious detriment of the Profession and the community it serves.

**Distortion of Engineer Identity**

Another difficulty arising from the confused image of engineers is the way in which journalists tend to identify the artefacts of engineering as the products of science. Occasionally, perhaps in the belief that they are being helpful, writers make reference to *applied science* when they mean *engineering*, but this
does nothing to retrieve the situation. Nor do euphemisms such as ‘technologist’ in an attempt to differentiate the engineer from the scientist and from the artisan.

Does it matter that there is confusion concerning the meaning of ‘engineer’? One outcome of misunderstanding the engineer’s role is that many young people mistakenly opt for the natural sciences at university, in the belief that scientists are responsible for the major engineering feats of the modern world. On graduation they find, no doubt to their dismay, that job opportunities in science are restricted. What is more, the world of ‘high tech’ work in industry is not open to the majority of them, since such work is the domain of graduate professional engineers. Consequently, the social cringe preventing an accurate projection of the image of professional engineering seriously misleads many young people regarding career choice. This is one of the reasons that countries still suffering from the ‘British malady’ are producing comparatively large numbers of science graduates and underemphasising engineering education.

Those engaged in the formulation of policy put much emphasis on the importance of science and ‘technology’. Similarly, analysts of science policy and economics fail to comprehend the significant contribution that engineers make to industrial R&D. As a result, engineering research, education and the engineering profession itself get short shrift. Yet engineering is crucial to the economic prosperity of industrial nations. Science is of substantial cultural and social significance and contributes to the world’s stock of knowledge. But, as an examination of the record of the successful industrial nations of the Pacific Rim confirms, economic success has long been associated with an emphasis on engineering rather than science.

There is no doubt that engineers have not helped themselves by their passivity in the face of onslaughts on their status, as discussed in Chapter 15. In Britain the problem goes beyond mere passivity, as demonstrated in official adoption in the 1970s of the oxymorons ‘Technician Engineer’, and the more recent ‘Incorporated Engineer’ to describe para-professionals and engineering technologists. In Australia the terms Engineering Associate and Engineering Technologist were adopted and became well accepted, but the apathy of IEAust discussed in Chapter 15 seems likely to undermine the differentiation from engineer these terms provide.

There will always be those who seek to boost their own prestige by attaching ‘engineer’ to their job title in one way or another. The American Dictionary of Euphemisms and Other Double Talk suggests that there are 2,000 examples of the use of this ‘vastly popular title for elevating the status of occupations’. The massive scale of the problem makes it daunting, but a serious and determined counter campaign by the Profession of Engineering in Australia, US and UK would do much to retrieve the situation. Unfortunately there is no sign that there is the will within the collective professional body to take action, and the problem seems likely to continue. The detriment to the economic progress of the community therefore will remain unresolved.

Conclusion

Australian professional engineers are well qualified and prepared intellectually to make major contributions to the national economy. Their contributions are limited by negative government policies concerning Research and Development, and the lack of enthusiasm among Australian manufacturing industries to undertake R&D. The performance of Australia in manufacturing for export is improving, but there is a long way to go to match the leading industrialised nations, including those in the Pacific neighbourhood as illustrated in Appendix B.

A major handicap for the Australian Profession of Engineering, in making an optimal contribution to national prosperity, is the appalling state of media and public awareness of the value to be derived from professional engineering activities. While the occupational identity of Professional Engineers is made subservient to ‘science’, obfuscated within ‘science and technology’, and allowed to be usurped by para-professionals, the situation is unlikely to change.

In view of the entrenched attitudes and ignorance of the media and many industry enterprises, the solution has to be in the hands of the Profession itself. In view of the findings of Chapter 15, it would be optimistic to seek solutions from the present professional body where responsibility normally would be expected to lie. However, there are signs of a new professional paradigm being developed, as considered in Chapter 17.
Chapter 17
Professional Employment in a Civil Society

By Brian E Lloyd

Questions about the Future

Questions arise concerning the future of engineering. Are engineering people to continue the trends of the 1990s as technical functionaries, adapting industrial age ideologies to the bidding of masters imbued with the brutalities of economic rationalism and slash-and-burn management? Or will they contribute to a renewal of civil society and take responsibility for the social and human, as well as the technical and economic consequences of engineering work? Would it be realistic to expect engineers to influence such matters? Can we expect to see engineering work take on radically new forms? Will engineers have the imagination and the courage to take control of their destinies?

Engineering as a civilian occupation arose out of the Industrial Revolution when the role was to build infrastructure and harness machines to commercial purposes. It evolved during the 20th Century to serve the world well, including harnessing solid-state electronics to make the information age possible.1 Industrial age ideologies continued to inform the command and control organisations of engineering during the 20th Century, providing certainty in careers leading to management where technological expertise was left behind. The paradigm shift described in Chapters 5 and 15 was an extension of the industrial age model until the information age, globalisation and economic rationalism overtook the old value systems and social constructs. Information technology now dominates the shaping of engineering organisations and the way they do business. In the early decades of the 21st Century globalisation is likely to be a dominant factor in shaping markets, projects and systems dependent on engineering. There is likely to be a turning away from the harshness of economic rationalism towards a more civil society. Will professional people in engineering take a leading part in that movement, or will they be left behind simply as clever workers while leadership is taken by others?

Some ideal engineering environments undoubtedly exist in modern professionally conscious organisations, but they are not universal. At the other end of the spectrum, corporate restructuring, downsizing and concentration on the short-term that eliminated job security and destroyed corporate engineering memories accumulated over generations, and so destroyed an intellectual infrastructure that will take decades to rebuild. Many young graduates found themselves in professional blind alleys, disenchanted and rejecting engineering as a career. The hope is that such an aftermath of the 1990s might be short-lived. We examine some of the realities of engineering employment, the good and the ugly, to see behind a rationalist conventional wisdom that masks a need for active pursuit of excellence in a civil society in which people can optimise their contributions. We address the future at a number of levels:

- Nature of engineering employment
- Knowledge-based organisations and maintenance of engineering knowledge
- Work arrangements in the 21st Century
- Professional employment arrangements for the 21st Century
- Professional society arrangements in the 21st Century

Nature of Engineering Employment

Employee Environment

What engineers do at the turn of the 21st Century is increasingly multi-faceted, making new calls upon education, experience and CPD, communication of ideas and mobility. The range of personal priorities, ethical beliefs (or non-beliefs), and approaches to engineering practice and social responsibilities, have diversified beyond measure. Global enterprises share engineering knowledge throughout the world. Many consulting firms have merged to form multi-national and multi-functional enterprises. Engineers move between employers and between countries, requiring knowledge that transcends professional work patterns and disciplines, across languages, cultures and national prejudices. Other engineers work in small or medium enterprises (SMEs) in support of larger companies, or as sole practitioners. Many graduating engineers go straight into non-engineering roles where their education is valued. Large numbers face casualisation of employment. There are expectations of a continuing shift from resource and manufacturing to service industries, in a climate of self-regulation and competition.2
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What might be the means by which future engineers will make their contribution to the world? For those who remain in engineering, the principal means surely will continue to be in development and application of engineering knowledge in a variety of organisational settings:

- Large employers, less hierarchical than in the past but managing people in organisations will still be a role for some: leading teams in one project after another will be a role for many.
- Engineers, in salaried, contract and contingent employee roles: with a variety of lateral relationships.
- Many engineers as contract salaried employees: with no long-term commitment to an employer and an expectation of a series of such engagements in a career.
- Many engineers self-employed as contractors: most as short-term contingent employees.

An estimated 20 per cent of engineers in 1999 were self-employed in one form or another, and that was expected to increase. Approximately 10 per cent of the APESMA members were self-employed, increasing possibly to 25 per cent by 2010, and ultimately 50 per cent (Vines 1999). In 2000, over 80 per cent of the PELF were in the private sector. The IIEAust estimates that 25% of Australian engineers could be working overseas in the future. The typology of employment modes in the new world therefore is:

- Salaried employee: as a member of staff of a company with long-term expectations, some overseas.
- Contract employee: remuneration packages for term contracts, perhaps renewable.
- Contingent employee: short-term, on agreed hourly or daily rates.
- Consultant: sole practitioner, fee for specific task, project or professional service.

All but the first category represent casualisation of professional engineering work.

The Engineering Practice Perspective

Transfer of engineering employment out of government departments, privatisation of utility enterprises, and downsizing and outsourcing of activities not seen as 'core' functions in all enterprises, dumbs down engineering capability by comparison with the high engineering expertise previously accumulated and nurtured as vital for effective engineering operations. The loss of corporate memories, and the wide practice of employing 'project managers' without engineering qualifications or background, has left many enterprises incapable of specifying their engineering needs, or a capacity to judge whether externally provided engineering services are adequate. When such an enterprise hires young engineering graduates and employs them on clerical tasks until they are 'mature' enough to be cast as 'project managers', they are deluded concerning the professional expertise derived from real engineering experience essential for specification and management of engineering projects.

When non-technical managers do not understand the need for professional engineers, and the highest level of expertise deployed is at trade level, it should not be surprising that engineering facilities or process plants fail. The engineer, who is 'on tap rather than on top', then is brought in to rectify the situation at minimal cost, and then to go away until the next such occurrence. The non-technical manager knows no better, and the engineer is unable to apply the continuity of expertise needed to establish and oversee technical protocols to ensure adequate operation and protection of health and safety. Uninformed clients tend to act in the belief that engineering services can be 'bought off the shelf' when they determine the need. The ultimate outcomes have to be a general dumbing down of professional engineering expertise, but heightened individual ethical obligations for maintenance of professional expertise.

Despite the downside trends of the uninformed client problem, the loss of identity of engineers and misuse of the title of 'engineer' have not been universal. In some enterprises there is a higher consciousness of 'what engineers do'. In some consultancies and corporations there is a greater awareness of engineers and their activities. For example, by removing the public utility umbrella through privatisation, the individual engineers representing these bodies are no longer perceived as 'public servants'. An outcome in some situations is that engineers are given greater recognition as the technically skilled people responsible for maintaining (or in some cases failing to deliver) products and services essential to the community. For example, in the process of formulating a proposal and justification to engage a contract engineer, it is necessary that all levels of the organisation recognise and agree that there is a need for the particular engineering capability. If the uninformed manager were to argue that the engineering resource were not required or could be delivered by different means, and a disastrous outcome ensued, or systems or equipment failed, in a traceable and accountable organisation such failure would provide feedback to (and about) the manager, and reinforce the need for engineers in the organisation. The downside of this feedback loop is that failure may have tragic consequences, impacting upon safety and assets, and in some cases the public. The profession of the future must learn to manage such risks.
Organisation of Engineering Knowledge

The Organisation of the 21st Century

What will the enterprise of the 21st Century be like? The question was addressed by the remarkably prescient Peter Drucker in 1988, predicting that by about 2010: 'the typical large business will have half the levels of management and one-third the managers. . . . Work will be done by specialists brought together in task forces that cut across traditional departments. . . . Behind these changes lies information technology. Computers communicate faster and better than layers of middle management. They also demand knowledgeable users who can transform their data into information.' He goes on: 'Information is data endowed with relevance and purpose. Converting data into information thus requires knowledge. And knowledge, by definition, is specialised. . . . The information-based organisation requires far more specialists. . . . in operations, not at corporate headquarters. . . . the need for service staffs - that is, for people without operating responsibilities who only advise, counsel, or coordinate - shrinks drastically. . . . Knowledge will be primarily at the bottom, in the minds of the specialists who do different work and direct themselves.' The new organisation thus is operated by knowledge workers in flat structures with lateral relationships largely replacing hierarchical command and control.

Previous engineering career expectations of 'moving into management' have been replaced by more limited advancement in engineering practice roles. This lends force to Drucker's further question: 'With the number of middle-management positions sharply cut, where will the information based organisation's top executives come from? What will be their preparation? How will they have been tested?' Therefore the challenge for ambitious engineers is to acquire the broad vision and business knowledge and skills to step up from engineer practitioner to enterprise leader. For the career engineers unable to make that step, the challenge is to keep up with technology while retaining enthusiasm and satisfaction. Drucker's perspectives were expressed before the fall of the Berlin Wall, and his prescience has to be overlaid by further factors of change and reservations about computers supplanting human intelligence.

Throughout Phases 1 and 2 of engineering, the great achievement was machines reducing repetitive physical work. The pursuit of many engineers in the new age is to apply technology to situations emphasising knowledge and brain power, as the third core factor with capital and labour. According to James (1999) this is not straightforward: the 'central challenge of businesses has been to identify and repeat the same formulas for success. . . . To achieve a consistent return above the cost of capital, businesses usually cannot afford to keep reinventing the way they generate money. If anything, the demands by the investment community to achieve predictable and continuous returns above the cost of capital have intensified'. The result is that chief executives tend to concentrate on the short-term and reject new ideas. They want packaged knowledge that does not require thinking, and intelligent computer systems to provide decisions, but they do not understand the inability of machines to exercise the consciousness needed to emulate human judgements and to act upon knowledge. Could this point to a future revival of dependence upon engineering knowledge in middle management?

Expanding Engineering Knowledge

Engineering knowledge continues to proliferate. Kennedy (1999) couples knowledge with communication and states the obvious not always understood: a successful enterprise in a competitive environment can survive only if its people are properly equipped, informed and motivated. Further, engineers must build upon their education and experience and the continuous maintenance of knowledge to develop their talent to the fullest extent. 'Each must seek to learn and understand all they can and attempt to communicate with others all they can. . . .' Dr Kennedy was Chairman of PB Power Ltd and President of IEE in 1999. His ideals reflect the professionalism expected of long-term employees in large enterprises. But the prescriptions do not reflect the reality that much of engineering employment is fragmented, transient and individually competitive. In such circumstances an expectation of communicating with others in ways that would reduce an individual competitive edge would be fantasy. This, of course, raises the question: what of enterprise memory, creativity and innovation if a preponderance of knowledge workers are in transient arrangements?

Initial Personal Development

Responsibility for initial professional development and subsequent career CPD also are issues in the world outside the ideal large employer. The need to maintain and enhance professional competence is not new. What is new, and uncomfortable, is the speed at which knowledge becomes outdated and in
need of extension and refreshment. The challenge starts the day after graduation. The half life of engineering knowledge in some areas may be as little as 5 to 7 years (Midwinter 2000). Engineering courses struggle to cover the core science and technology to support even a single specialism such as electronics, and an engineering degree provides little more than a 'career starter kit'. But economic pressures cause Australian employers to insist that recruits contribute to business output as quickly as possible. The outcome can be courses of such reduced breadth that graduates are ill-prepared for a future of change. Further, there has been a tendency to exhort the private sector to provide initial professional development of new graduates previously provided mainly by the public sector, but realities have to be faced:

- While many engineering-based companies hire and nurture new graduate engineers on the clear understanding that such people are the life blood of the enterprise, most companies are unlikely to provide initial professional development for any but the graduate engineers they intend to retain, but not for others.
- Many companies rely upon contract and contingent professional employees, and do not hire new graduates or invest in initial professional development for them.
- Some companies take on graduates and then select a few to be developed as project managers. The rest are discarded without preparation for subsequent employment.

In the new world, an expectation of an employer providing initial professional development is likely to be unrealistic for a large proportion of new graduates.

**Continuing Personal Development**

In the new world of employment mobility, CPD both in technology and human skills is essential for careers to be successful, productive and satisfying. The mantra for companies is: 'innovate, seize opportunity, change the rules, learn faster than your competitors, or die' (Midwinter 2000). The mantra for every engineer has to be: 'innovate, seize every opportunity to learn, change the old rules and rely on yourself, learn faster than your competitors, or get out of engineering'. As IEAust (1999) notes, *skill security* in the new employment world is increasingly more important than *job security*. It is all very well to admonish the private sector about obligations for CPD, but again realities have to be faced:

- While many companies nurture their professional employees and commit to CPD, others rely upon contract and contingent engineers for whom CPD is not an issue unless of immediate use to the company.
- Many companies take on graduates for their potential to contribute immediately. Those who survive have to develop competencies for immediate needs, and CPD is directed only to that.
- Many engineers are obliged to arrange their own CPD, especially as it relates to longer-term career development and their obligations as professionals. The individual meets the cost in both time and money.

In a world of long hours, high pressure and job mobility, the questions engineers ask are: When will I have time for CPD? Can I afford it? Can I earn enough to take time off to do a course? While distance education enhances accessibility, many have great difficulty finding time for CPD to meet IEAust requirements for retaining Chartered and Registered status. There are inherent trade-offs in maintenance of engineering expertise:

- The engineer retains a competitive edge in employment, but contingent employees must meet the cost.
- The enterprise supporting CPD for its engineers improves its competitive edge for remaining in business.
- The employer (or client) engaging contingent employees benefits from CPD: the enterprise improves its competitive edge through competent engineers, but remuneration must reflect the cost of their CPD.

**Work Arrangements in the 21st Century**

**Knowledge as Intellectual Capital**

As the 20th Century drew to a close, a conventional wisdom in financial markets had it that old industrial enterprises were struggling in the face of competition from the nimble, information-based organisations. While Kennedy (1999) wrote about the knowledge needed to underpin enterprises that actually make things, many 'new age' writers envisaged knowledge as information, and an end in itself. They saw the 'information age' as concerned with collection and storage of data, without understanding there is no point if data is not turned into knowledge and put to creative use. Even in the new world there remains a need for enterprises that make things and other enterprises to build, operate and maintain facilities and infrastructure. The intellectual capital underpinning such knowledge and material effort is what engineers are about.

During the 20th Century the swings and roundabouts in enterprise management may be seen in
terms of cyclical revolutions that swept the world as one theory was replaced by another, then seen as the solution to all problems - until the next one came along. At the beginning of the 20th Century there was the engineering approach of Frederick Taylor, seeing people as extensions of machines. Then there were human-centred theories envisaging organisations as social systems. But in both there was a conventional wisdom that people were lumped in with other costs of owning and operating a business. In the 1990s slash and burn management got rid of people to improve the immediate bottom line, without regard to the need to nurture and retain intellectual capital as the principal underpin of long term enterprise viability.

Perhaps the slash and burn phase of management will run its course, but there is unlikely ever to be a return to the old hierarchical organisation, and the new model is likely to continue a heavy reliance upon casualisation of employment. Therefore the two elements of the human capital equation, the people and the structure of organisation, will take new forms. Large enterprises will adapt and arrange their organisations to optimise competitive advantage. However, given the demonstrated past absence of intellectual understanding of such issues among the leaders of many enterprises, and among professional people at large, can we be confident of the evolution of a new model of interpenetration between the enterprise and the professions upon which they depend? How will enterprises and their contingent professional employees cope with a need for developing and maintaining intellectual capital and corporate memory?

The Changed Professional Work Place

Social analyses in the book *Corrosion of Character* (Sennett 1998) explored how work-place change in the 1990s destroyed a quality of life that used to bind people together in organisations. The most damaging personal consequences were withering of social relationship networks previously nurtured through shared experiences in long-term employment. The traditional job provided income, future security, career advancement and individual social satisfaction derived from occupational identity. The new-age approach of project teams formed and disbanded allows for no permanent attachments.

The new age CEOs who concentrate on the short-term stultify engineering development, by creating an illusion of enhancing short-term wealth by so-called 're-engineering'. Strategies of constant change develop a chameleon culture in which the organisation seeks to re-invent itself to become leaner, flatter, more flexible and more profitable. In the process carefully cultivated engineering knowledge and skills are devalued as practices, product designs, competitor intelligence and capital equipment are consigned to the scrap heap. The end point often is a moribund enterprise incapable of long-term survival. By the time that is realised, the CEO has 'moved on' with a significant increase in personal wealth, leaving a trail of ruined lives and an enterprise at risk.

When the cult of short-termism overtakes an enterprise, it destroys trust and mutual commitment between people (Sennett 1998). It corrodes character because valued qualities become adaptability, openness to change at short notice, and preparedness to take risks continually. Such qualities are expected to replace the attributes of good character: loyalty, stability, mutual commitment and the pursuit of long-term goals. There should be no surprise that when an employer exposes employees to the brutalities of 'downsizing', those who remain see the employer as disloyal to them and cease to make a personal investment in their contribution to the enterprise. Colleagues become competitors as the number of jobs shrinks, and a culture of detachment becomes a better way of dealing with people than behaviour based on loyalty and service, especially when an erstwhile colleague begins handing out dismissal notices.

The past stable social institution of the employing organisation contributed to a civil society: loss of social connectedness in employment diminishes society. In the new world many engineers have to operate as contingent employees outside the traditional social framework of an enterprise work place. Change came in the same era as the diminishing professional connectedness among engineers through allegiance to IEAust, compounding a reduction in ethical commitment. Such trends erode the very foundations of a civil society. For many engineers who once knew trust and friendship, and who valued ethical contribution to the public good, there is now self-centred competition and loneliness. But there have been engineers on both ends of the social upheaval in work. There are some engineers imbued with economic rationalist ideologies and willing to contribute to the brutalised processes of so-called re-engineering of enterprises. Such engineers place themselves on one side of a social divide. There are many more engineers on the other side, and it is with them that we are concerned.

In the new Darwinian world individuals on both sides of the divide put effort into strategies for
survival and preparation for an uncertain future. In a civil society more than that is expected of professional people: ideally there will be a collective spirit of helping colleagues who are struggling, and mutual support in values and interests held in common. The true professional will understand that in return for professional status, there is an obligation to share privileges with colleagues and to contribute to societal good. In the new world such values are more important than ever, and a new professional model must form a professional society that will enable members to build connections in new ways. This implies a changed professional model.

**Guild Model for Professional Work**

For many people in the 1990s, making a living began a shift back to the pre-industrial mode of self-reliance and income insecurity. For many professional people the managerial revolution of flexible non-traditional employment obliterated the concept of a secure job. As a response, for workers who no longer have a continuing affiliation with an employing enterprise, Laubacher and Malone (1999) propose the idea of associations of employees based upon common interests and needs and using the metaphor of the medieval guild.

While admitting that new ways of working at times result in improved economic efficiency and flexibility, they ask: 'what about the individuals in these flexible networks? Where will they go to fulfil the human needs that are satisfied today by large organisations? How, for instance, will they find financial security? Who will provide for their . . . retirement? Will they be lonely, working all day with their customers and suppliers, but never with colleagues?' The issue became highly polarised in Australia: the business press and conservative politicians extol the benefits of flexible work and ignore human costs, while others emphasise the human costs without acknowledging possible enhancement of overall efficiency and effectiveness.

Laubacher and Malone point out that working as an employee, dependent on steady income that does not vary with the ups and downs of the employment organisation, became the norm during the 20th Century. Prior to the Industrial Revolution most people worked for themselves as farmers, artisans or small shopkeepers. Many belonged to some form of association that 'provided mutual aid, means for finding future work, and a setting where learning and sharing of skills could occur. These organisations offered a forum where workers could meet and be acknowledged by their peers. Some . . . most notably associations of skilled tradesmen - could trace their history back to the middle ages [and] the medieval guild movement.'

Transferring this idea: a professional guild could provide for human and economic needs for a stable base and income security for people moving from one engagement to another. The guild also could facilitate a path of upward career mobility, social as well as occupational identity, a congenial social environment associated with work, and provisions for health and retirement. The same 'engineering guild' could embrace salaried and contingent employee engineers and technologists having common interests and needs, and support them as the locus of social interaction, recognition and professional identification:

- to ensure protection against unemployment or under-employment,
- to provide work placement services for permanent and temporary job vacancies,
- to provide advocacy and legal services individually and collectively,
- to arrange low cost Internet access and other technological supports, and
- to facilitate initial and continuing personal development.

While independent professionals carry unemployment insurance, the guild could manage unemployment risks through member contributions to a guild fund while they were in work, in return for a guaranteed minimum income between jobs. Such a scheme would motivate members to help colleagues to find engagements and to keep up to date with their CPD, and exert social pressure on any members not trying. The guild would assist members to find work, and might also bid for specific engagements for groups of members. This function would entail establishing and verifying a professional register recording work engagements undertaken. The approach could extend to classification standards for defined levels of knowledge, skills, experience and CPD coupled to pay bands.

Facilitation of personal development would be an important guild function, both in sponsoring initial professional development programs with co-operating employing bodies, and in arranging CPD. Experienced members could become mentors for graduates, perhaps in shadowing arrangements. Through life-long personal CPD for members, and in matching the attributes of members to available
work opportunities, the interests of the guild would be closely aligned with those of the employing organisations. While the traditional collective pay representation role assumes an adversarial relationship between employees and management, under the guild arrangement the representation role would assume harmony of interests. The guild could fulfill another important social need by organising gatherings for networking and advice, as the primary professional entity with which members identified. In place of the traditional social identification with the employer, the member's primary social and occupational identity would be associated with the guild.

Professional Employee Arrangements for the 21st Century

Strategic Vision of APESMA

A world conference organised by APESMA in Melbourne in 1999 examined how engineers were preparing for employment in the 21st Century. The Executive Director of APESMA described how the Association was addressing employment issues and services associated with professional employment (Vines 1999). He pointed out that in the 1980s APEA had been caught flat footed on how to respond to changed employment circumstances. While initially seeking to have 'de-engineering' addressed through the Industrial Relations Commission, the need for a proactive approach quickly was recognised. Vines (1999) set the scene:

For engineers to be seen as more than ‘technocrats’, and importantly to be able to make a contribution from a business perspective, we must develop skills relevant to business decision making. Engineers must see themselves as business people and the engineering profession must be seen by the community as . . . technically competent, but also . . . within the mainstream of business. In other words we must seek to develop recognition within the community of:

- Engineers with business acumen
- Engineers as (managed) risk takers
- Engineers as business people
- Engineers as equity players (investors)

During the 1990s employee associations and unions debated how to balance traditional collective representation against a broader approach to member service relevant to the changed employment environment. Prompted by experiences of elected officers, the Association commenced strategic planning in 1987 to establish a cross-industry organisation for professionals. In 1991 APEA merged with the Association of Professional Scientists of Australia to become APESA. APESMA resulted from further mergers covering architects, senior managers, pharmacists and railway professionals. Scenario planning in 1994 sought to envision APESMA in 2004, with a centralised industrial relations system in a decentralised environment of most members employed under individual arrangements. Planning steered the organisation to a preferred future rather than passively allowing external events dictate its course. APESMA became a successful association of employees with high satisfaction among 25,000 members.

Table 17-1
Typical Profiles of Managers
(Summarised from The Manager of the 21st Century, Boston Consulting Group.)

<table>
<thead>
<tr>
<th>1970</th>
<th>1995</th>
<th>2010</th>
</tr>
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<tbody>
<tr>
<td>The Autocrat</td>
<td>The Communicator</td>
<td>The Leader/Enable</td>
</tr>
<tr>
<td>Male</td>
<td>Male or female</td>
<td></td>
</tr>
<tr>
<td>Anglo-Celt, Brit/Australian</td>
<td>Anglo-Celt, Australian</td>
<td>Wide range of ethnicities</td>
</tr>
</tbody>
</table>
management skills (the Karpin Committee), established in 1992 and reporting in 1995. The report included the profiles of managers summarised in Table 17-1, believed by Vines to represent trends in management for future engineers:

The profile of the 21st century manager provides an important framework for aspiring engineer managers and employers of engineers . . . in terms of the development of relevant skills for engineers to assume leadership positions in their organisations . . . . The 21st century manager profile also provides significant clues for young graduate engineers as to how they might go about preparing for senior management roles . . . .

No longer do we have the luxury of the engineer being able to implement a solution without serious regard to the business case to support that solution. For engineers to effectively argue their case they must be able to present their solution in terms which non-technically qualified people can understand. This suggests that engineers need to be able to speak the language of accountants, lawyers, marketers, economists and human resource professionals. As it is unlikely that very many, if any, of these professionals will ever be able to speak the language of the engineer.

The engineer equipped with . . . these non-technical disciplines is at a significant competitive advantage. . . . While [not] every engineer necessarily requires business skills, as there will always be a requirement for highly technically qualified engineers, the future influence of the engineering profession and our ability to assume leadership positions in organisations is dependent on us being able to speak the language of the business community and present our solutions within the context of that language.

The leaders of the Association believed the changes from traditional employment would continue, and engineers working as contractors or consultants would take on a small business mindset different from the employee engineer. Vines saw a trend of engineers taking equity positions in companies and projects, embarking on management buyouts and, as consultants, taking a portion of their fees as equity in a project. The APESMA/Deakin MBA (Technology Management, Chapter 12) makes a major contribution in this area.

**Member Services**

APESMA saw the need for legal assistance to members on contracts, and encouraged industrial negotiators to acquire legal training. Establishment of *APESMA Solicitors* provides access to a range of legal services. The membership system was remodelled to establish member histories for delivery of a consistently high level of service in handling inquires from individual members. The Association achieved quality certification for internal procedures and processes, as the first employee association in Australia to attain such certification.

The Association also provides members with Internet access to a range of information and E-commerce based services. Provision of CPD for members through postgraduate education and other programs became an outstanding success, as described in Chapter 12. The Association also saw the need to provide assistance for members in gaining employment and set up *ETM Recruitment* as an employment agency. *Remuneration Surveys* organised and published by the Association for membership professional groups became the most authoritative of their type in Australia.

*APESMA Accountancy Services* provides members with a taxation service and advice on appropriate structures for self-employed members. Other services include a retirement benefits scheme, discounted telephone and internet access, and a range of personal and financial advisory services. Such services add value and appeal to the family unit, as the decision to pay the membership fee is increasingly made by the family unit rather than the individual. An increasing role was arranging for members to meet to network information relevant to their interests.

In 1990 the Association planned to expand assistance for self-employed members. The APESMA employment agency *ETM Recruitment* would act as a broker for self-employed and contract professionals, supported by indemnity and income protection insurance, legal and financial services, and advice on contracts, remuneration and employment intelligence. In these developments, APESMA moved a long way from its beginnings in 1946, and from the original focus upon establishment of adequate salary levels. However, the vision of the founders, as expressed in the *Aims and Policy* of 1955, encompass all such activities, albeit in ways that could not possibly have been foreseen:

It is the general objective of the Association to raise the status of the employee Professional Engineer, and in particular its chief aims are to establish conditions that will:

- Promote professional consciousness among Professional Engineers.
- Enable all Professional Engineers to maintain a standard of living in keeping with the reasonable needs of a professional [person].
- Enable and encourage Engineers to perform their professional duties to the greatest degree of efficiency and with maximum vocational satisfaction.
Professional Society for the 21st Century

A Strategic Plans of IEAust

Towards the end of the 1990s the IEAust developed a Strategic Plan 1999-2003 and revisions to the national structure in report IEAust 2000 Plus. A Directions Statement looked ahead two years from 1998, envisioning service to members through five Program Areas.

- **Member Services**: to represent engineering in Australia and the region, increased membership by technologists and para-professionals, raising the profile of engineering in the community, better membership management, services and benefits, and database services for members, employers, agencies and clients.

- **Engineering Formation**: national and international recognition for accreditation, assessment of foreign qualifications, and Competency Standards.

- **Engineering Practice**: to ensure world best environmental, multi-disciplinary and cross-cultural engineering practice in a societal context; coordination of IEAust technical activities; involvement in Standards Australia; enhancement of the professional status of members through CPD and practice information; and encouraging research, development, innovation, commercialisation and technology transfer, international recognition and mobility.

- **Representation and Communication**: aims for effective communication with members, credibility of the engineering team within the community, and recognition of IEAust as the authoritative source of engineering information.

- **Governance and the Executive**: process based operations and flexible delivery of member benefits; improved communications with members and the community, industry and government; effective delivery of CPD to members; delivery of benefits and services members seek, especially career enhancement services.

An objective was to enhance opportunities for members and employer organisations to contribute to IEAust programs and activities, including accreditation and recognition, facilitating CPD, promotion and marketing, mentoring and career advice, recruitment and member retention and services, liaison with government, industry, and academic institutions, and international relationships with kindred professional bodies. This inward-looking list demonstrates the wide scope of the activities and responsibilities of the Institution, but little understanding of the changes in employment impacting upon members and upon the IEAust itself. It ignored collaboration with APESMA.

Member feedback was clear: professional recognition is a paramount concern. Professional society activities, local social and professional contact at meetings and networking, also were important. Nationally based functions concerning accreditation, recognition and representation were neither understood nor appreciated.

New Professional Model

The analysis in Lloyd (1991) shows that although the social organisation of engineering in Australia is not subject to disciplinary fragmentation, there is a different form of fragmentation. From a historical perspective, the fragmentation of interests of professional engineers began in the 1950s when APEA took the running on status and reward, the heart of the profession. When IEAust was left with the mind of the profession, it drifted out of the personal agendas of many engineers. At the same time, with its focus upon status, reward and membership services, APESMA without the mind failed to satisfy the personal agendas of the many engineers who rejected membership. The professional bodies are dependent entirely upon voluntary membership, and joining both requires payment of two sets of subscriptions. Neither body fulfils total needs: many engineers opt for one and not the other, but most opt for neither. Separation of the non-intersecting leadership groups of IEAust and APESMA also causes problems in the co-ordination of the employment interests of members.

The inter-related system of member needs is illustrated in Figure 17-1. There were some overlaps between the IEAust and APESMA in responding to member needs. For example, while IEAust makes the running on professional standards, the Association participates in their formulation and application. There is also some overlap in individual services to members. APESMA is attuned to serving the inter-
ests of engineers and other professionals in salaried and contingent employment, while IEAust is indifferent to such issues. The IEAust strategic plans were not attuned to the social changes impacting upon members of the profession at large, whereas the approach of APESMA attracts high approval from members (Vines 1999). The leaders of APESMA value the accreditation, recognition and learned society roles of IEAust, but just as IEAust ignores APESMA in its plans, the reverse also is true. Casualisation of professional engineering work makes the functions of both bodies important to the future effectiveness of Australian engineering, and neither can fulfill all needs acting alone.

The IEAust is seen by many as an old fashioned and top-down organisation, telling engineers what is good for them, while APESMA responds directly to changing member needs. For example, while IEAust was busy devising a CPD policy (a good thing in itself), telling members what was expected of them, APESMA responded to the changed employment situation by delivering postgraduate management education and an employment agency.

The ethical dimension can only be of value to the community when the reach of the professional bodies extends to the majority of potential members, therefore the objective must be inclusiveness, not exclusiveness, while maintaining occupational standards, role definitions and occupational identity. Effective professional bodies in the 21st century will attract allegiance when members and potential members see value in their subscriptions. A modern professional body catering for professional needs and operating according to clear objectives, will deliver value in:

**Recognition and Representation**

- Well informed promotion of unambiguous occupational identity, recognition and status.
- Qualification-based admission through accreditation and equitable evaluation of non-standard education, but never substituting experience for education.
- Systematic qualification-based titles, underpinning relevant status, work roles and values, for occupations in a work force system based upon interdependencies between occupations.
- Effective communication promoting recognition, status and professional consciousness, and involving members in decisions concerning ethical obligations, recognition and status.
- Representation of the recognition and status interests of members to the community, employers, governments and internationally.

**Employment and Practice**

- Well informed responses to the realities of employment and practice needs of members as: salaried employees, contract employees, contingent employees, consultant sole practitioners.
- Effective responses to the primary interests of members in:
  - practicing and contributing effectively and achieving vocational satisfaction,
  - continuity of an appropriate level of professional income,
  - access to a broad range of CPD, and
  - professional and social contact reinforcing values and opportunities.
- Communication affecting the interests of members, involving them in decisions concerning their work lives.
- Representation of employment and practice interests of members to employers, clients and governments.
- Influencing employers to understand the advantage of employing engineers who understand ethical values, and to persuade their employee engineers of the advantages of IEAust membership.

In particular, a professional body serving employee professionals will heed the advice of Laubacher and
Malone (1999) and develop services and activities on the following lines:

- Guaranteed minimum income in insurance, and advantageous rates for other practice and family insurances.
- A job clearinghouse matching members to work opportunities according to qualifications, attributes and experience, and collective bidding for appropriate specific engagements for groups of members.
- A database establishing and verifying the professional reputations of members, in a classification system for defined levels of knowledge, skills, experience and CPD, coupled to pay bands.
- Sponsoring initial professional development programs for new graduates with cooperating employing bodies, through income support, mentoring and shadowing arrangements with senior engineers.
- Facilitating personal practice, performance and survival-related CPD for all members.
- Promoting harmonisation of the interests of members with those of the employing organisations and when relevant, a collective pay representation in a situation of harmony of interests between the parties.
- Organising opportunities for socialising, networking and advice, providing the primary locus for social and occupational identity especially for members in non-traditional employment.

Other professional functions, such as dissemination of knowledge, conferences, public relations, influencing governments and international relations, only become relevant to individual members after the above core employment interests are served. APESMA is well along the way in presenting core services for members, and further development is likely. However, the diversity among engineers and people in related occupations is such that some will be interested in selected issues and reject others. There will always be professional people imbued with a 'rugged individual' self-image, rejecting any notion of collective organisation or mutuality of obligation, and they will have difficulty in establishing any claim to professional status.

Conclusion

During the second half of the 20th century the professional body role was shared between IEAust and APESMA. It is time for a redistribution of responsibilities. One thing is certain: it would be very foolish for IEAust and APESMA to divide the professional body role by aggressive competition detrimental to the good of professional people and the society they serve. Has the time passed for re-uniting the heart and the mind, or is there a long-term possibility that evolution might see the emergence of a new form of unified, inclusive professional body?

The world of the future could see a growing recognition that the most important assets of a corporation are the professional people who create and lead the work of the organisation. Of course, physical assets have value, as do software and intellectual property. The creative and prosperous (and surviving) enterprise of the future will understand that it cannot own people nor what goes on inside their heads. Such an enterprise will understand the need to provide a work environment in which professional people will want to stay and contribute to creativity and intellectual leadership. This is complementary to the idea of the corporation as a voluntary association, in which working 'members' are 'shareholders', who contribute intellectual capital, alongside the other shareholders who contribute monetary capital. The professional associations have a role in the evolution of such developments, in establishing a balance between a professional work force comprising salaried and contingent employees.
Notes to Chapter 17
1 Some ideas in this Chapter are informed by Latham (1998).
3 IEAust (1999): Hourly Contract employees 4.4%, self-employed proprietor or director 14.4%, including consultants. The
   survey figures are adjusted for retirees.
4 These thoughts are from Adam Newman, in an Assignment in the postgraduate study unit *Key Competencies in Engi-
   neering Practice*, delivered through EEA by Brian Lloyd.
7 Many ideas in this Section are sparked by Laubacher and Malone (1999).
8 *The Manager of the 21st Century* was prepared for the Taskforce by the Boston Consulting Group.
9 IEAust continues to obfuscate professional and para-professional status in statements such as this by application 'profes-
   sional' to members who include para-professionals.
Chapter 18
Engineering Beyond 2000
Brian E Lloyd

Introduction
Who would pretend to foresee the nature of engineering at the end of the 21st Century? Is it too fanciful to think of engineers in the early decades of the 21st Century contributing to the design of space stations, working in global enterprises operating 24 hours a day via new generations of the Internet? Some engineers operate this way already. Is it too fanciful to think that some engineers graduating in or before 2030 would walk on Mars? By century-end will engineers on Mars be building settlements and launching pads for further space exploration? Any such engineers undoubtedly will be employed by large corporations: who would risk being a contract engineer on Mars? However, social trends tell us that many other engineers are likely to be sole practitioners, reliant upon people and computer networks in their engineering practice. Can we imagine the computing power available to them in 2050, when we understand that it took only 50 years from the first transistor to place supercomputers on our desktops in 2000?

We cannot even approach such technical questions in this book. But we can imagine engineering in Australia beyond 2000 continuing to provide stimulating and rewarding work for a large number of engineers. Successful enterprises will continue to rely upon innovation and creativity as their life blood, will nurture graduates in their early years, and will nourish mature people through rewarding experience and CPD. These are the enterprises that will succeed.

As we peer uncertainly through the lace curtains of the future, this chapter concentrates upon professional engineers, but similar questions apply to the future social development and organisation of engineering technologists and engineering para-professionals. We assume a continuing existence of a professionalised occupation called engineering, while recognising that that might not be a valid long term assumption. While the segments of the engineering work force system can be expected to continue to evolve in new forms with different occupational identities, we need to remember that optimisation of workforce effort in the 21st Century still will require an orderly systems framework, whatever evolution might hold.

Sustainable Globalisation
The year 2000 marked completion of the first decade of the new era of globalisation, following the end of the divided world of the Cold War (Friedman, 1999). In the 1990s globalisation became an expression of the reality, the inevitability, the brutalities and the challenge of rapid technological change and economic integration that were sweeping the world. Globalisation brought an international labour market for engineers, privatisation of public sector infrastructure enterprises, and raised concerns for protection of public interest and national sovereignty.

In the world without walls, globalisation transformed the engineering workplace and the engineering role. For engineers and their colleagues, globalisation eliminated old lifestyles and produced new ones, rapidly eliminated old markets and created new ones, destroyed old industries and brought about new industries. It is a process still in progress: demanding that society move faster, work smarter and take more risks than at any time in history. Will it continue to bring the kind of employment change that makes losers of Australian workers and communities as Australian jobs are transferred to robots or foreign factories?

A major factor of change has been the democratisation of technology through digital electronics, telecommunications, computers and the Internet, enabling faster and cheaper world-wide communication and information transfer. The symbol of the new globalisation system is the World Wide Web, almost autonomous in its reach and nature. Integration of technology, finance, trade and information now influence the way people live all over the world. In many respects the new world is better than the old world. It is claimed that humanity enjoys the unprecedented prospect that living standards will quadruple within a generation. Given these challenges and opportunities, the world needs a strategy to make globalisation sustainable. Democratic nations need to adjust their approaches to health care, education, job training, the environment, market regulation, social security, financing the political process, and free trade. Adjustments are needed to enable society to get the most out of the globalisation system and to cushion its brutalities.

The first era of globalisation, to the 1920s, was aborted by the rise of socialism, communism and
Challenges in the New World

Aspirations for future Australian engineers and engineering technologists, as expressed in reports on reviews of education in the 1990s, are considered in previous chapters. The essential feature of the future practitioner, after all the idealistic requirements for the new graduate are boiled down, could well be a weakness: ‘The very strength of engineers as pragmatic problem-solvers can clearly be seen as a limiting feature - unless properly placed in a broader context. Until engineers can expect to be as much a part of framing the problems as they are of solving them, they will continue to be, and deserve to be, ‘on tap’ rather than ‘at the top’ (Johnson (1996). We therefore return to the questions like those posed at the beginning of Chapter 17:

- Are engineering people to continue as technical functionaries, doing the bidding of masters imbued with the ideologies of economic rationalism?
- Or will they contribute to a renewal of civil society and take responsibility for the social and human, as well as the technical and economic, consequences of their work?
- Will the people in engineering have the imagination and the courage to take control of their employment agenda, and the professional arrangements, that will enable them to determine the manner in which they optimise their contribution to society?

Of course, achieving change of this kind is beyond the power of most individuals, but if large enough numbers of engineers band together in a professional association that will pursue related objectives with vigour and enlightenment, the world of engineering could be changed for the better, both for the community and for individual engineers. Such an outcome could not be achieved unless inspired leaders emerge from the ranks of professional engineers.

An inhibiting factor, however, is that engineering is a technical activity, rooted in analysis and synthesis, and requiring technical and managerial judgements that lead to tangible outcomes. It would not be engineering if that were not so. Such characteristics do not provide fertile ground for the leadership needed for the profession. However, engineering also is directed to economic and community benefits, and engineers cannot escape the fact that their occupation is a social activity imbued with ethical, commercial and political dimensions. Successful engineering depends upon engineers who can lead, communicate, arrive at solutions after considering alternatives in a social and environmental context, and consult with the people likely to be affected by them. Further, successful engineering of projects or products have to accommodate cost, legislative and environmental constraints, and marketing and community acceptance. There is an expectation in these sentiments, developed in Beder (1998) and by others, that the future new graduate will have to be a paragon. Be that as it may: the future success of engineering have the imagination and the courage to take control of their employment agenda, and the professional arrangements, that will enable them to determine the manner in which they optimise their contribution to society?

Such a requirement of engineering education would be unrealistic. The challenge for education not to try to turn out super graduates who will be expert from day-one in everything from expertise in a specialism, great inter-disciplinary breadth, and having the social and political savvy to right the wrongs of the world. The challenge for engineering education is to provide a sound foundation to enable the new graduate to undertake the experiential development needed to understand the world of engineering and the ability to learn to contribute to it. But it cannot be all up to education. A second challenge lies at the feet of the profession itself: to develop in new graduates the additional educational and professional foundations for leadership, self-reliance and courage, social understanding and professional consciousness. These are the essential attributes required to be effective in professional development and survival,

The environment within which we work has been transformed as companies, manufacturing development and research have all taken on a global dimension. Most development programs now involve the interaction of many different scientific disciplines, so that knowledge flows seamlessly from the mathematical, physical and biological sciences into engineering where it fuses with yet more information from business and markets to evolve towards new products.

The level of complexity now possible has also triggered a new approach to the design of complex systems. Knowledge has traditionally been structured and taught in self-contained compartments. However, increasingly we find systems described in terms of a layered model. . . . The specialist sub-fields so beloved of traditional electrical engineers have largely disappeared into the lowest hardware layer, with most of the system design now being carried out in an abstract, almost mathematical way and expressed through the generalised software and hardware system of the upper layers.

The layer model carries with it some further messages for electrical engineers.

The extent to which it maps closely to the much more generalised three-layer model of society as a whole shown in Figure 18-1 highlights the importance of engineering systems. Similarly, the spread of various university-level disciplines emphasises the way in which engineering uniquely spreads firmly into all three layers of society, finds common cause at some level or other with all other disciplines and differs significantly from science.

Returning to the educational challenges this poses, it is clear that, in an ideal world, engineers should be schooled in their subject to considerable depth and breadth, as well as being conversant with business, commerce, markets and people. However, this requirement has to be set against [demands upon the university] sector that must deliver shorter, cheaper courses, not longer, more expensive ones.

The typical mix of subject matter offered by many [universities] today in EE is shown in Figure 18-2 in general terms and virtually excludes many traditional EE issues. However it is clear, given the vast scope of our field, that the level of detail will be very limited so that before they can be productive in their first job it will almost certainly be necessary to expand a graduate's job-specific knowledge. Since the courses that graduates typically take in their final year and their final year project could go some way to that end, linking course choice to first employment would make sense but is not logistically possible in most cases today. And we should note that the job-specific knowledge might involve expanding the range of topic

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**Figure 18-1** Disposition of University Disciplines Related to a Layer Model of Society (Midwinter 2000)

**Figure 18-2** Mix of Major Topic Areas for a Modern EE Graduate (Midwinter 2000)
areas shown in Figure 18-2.

Continuous learning then follows, adding updating detail or reskilling the individual into new fields, the latter becoming ever more important as the pace of change quickens. Unlike first degree learning, most of this will be undertaken on a 'just in time' basis. However, given the existence of just in time learning provision, what does a first degree really need to cover? The answer is self evident - just enough to allow one to be effective in one's independent study.

Self motivation, learning skills and an understanding of the enduring fundamentals and concepts, mathematical or numerical analysis etc. This is a more restricted objective than many would seek for a first degree and leads to the question of whether shorter, cheaper degree courses could be desirable in the future.

Market pressures will certainly favour them as universities are forced to sell themselves in terms of 'value of money' to the applicant, so how might quality be enhanced and cost to student reduced? Some pointers already exist [in cooperative arrangements with engineering companies.]

Conclusions
Some clear messages emerge from this discussion of electrical engineering education and training:

The first degree provides at best an overview of a part of our subject field coupled with a foundation in some of its enduring principles.

Financial constraints are crippling universities' ability to offer access to 'state-of-the-art' facilities for project work. This is now much better done in industry, perhaps through a thin sandwich model.

The term 'qualification' as traditionally understood by the engineering profession has lost much of its meaning as skills become increasingly ephemeral. The emphasis has shifted to 'just-in-time learning', in which staying up to date counts for more than the degree one did ten years ago.

First degree programs at attractive prices will soon be as important as programs setting high academic standards. This will generate space for much innovation in both structure and delivery.

Leading companies are developing, with universities, new ways to carry their staff through first degree, into first employment and onward throughout their careers. Such schemes seem certain to have a profound impact upon the [university]-industry relationships of the future, with the divide between learning and working increasingly blurred.

Learning and employment are increasingly global. Employees, students, teachers and employers beware!

Finally, the IEE's own role must adapt to this changing scene if the Institution is to retain any relevance to professionals and their employers. This will require much faster change than we have been accustomed to.

Perceptions of Engineering in the UK
To balance Midwinter’s views, a report called The Universe of Engineering published in the UK in June 2000, provides an indication of the thinking among leaders of the Royal Academy of Engineering and the Engineering Council (Malpas 2000). A sample of that thinking, to the effect that they define the 'engineering profession' as including chartered engineers, incorporated engineers [technologists] and technician engineers (sic). The correct term for the latter, as registered by the Engineering Council, is 'engineering technician', and inclusion of this para-professional group in the 'profession' is typical of the woolly thinking presented.

The report does have value in defining a very wide net covering engineering-based activities, but the woolliness of expression throughout throws doubt on the whole report. The grain of truth embedded in it, but not expressed overtly, is that 'engineering', as we know it in Australia at the professional engineer level, is likely to become enmeshed in a wide range of related 'professional' activities and qualifications, and that perhaps in the long term the occupation is likely to acquire a much broader scope. The report demonstrates clearly that in the UK the title 'engineer' has lost its meaning as a professional occupation, as it concedes validity to a wide application by qualified and unqualified people, in many occupational areas and at all levels of intellectual attainment. The alarming aspect of the report, therefore, is an unwillingness in the UK to identify any validity in defining work-force categories and associated roles in relation to the education necessary for effective performance in such roles.

The Malpas paper was not an isolated event. the March 2001 issue of IEE News, announced the formation of new body, the Engineering and Technology Board, soon to replace the Engineering Council. The broader organisation will embrace the whole 'engineering and technology community', and shift the focus from the engineering profession [however that may be defined]. The aim is to establish a much
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stronger, much more inclusive partnership, to make the best of the UK’s valuable engineering and technology talent. The Board will have a fundamental role to galvanise the whole of the community in the key task of promoting the engineering and technology professions and the contribution they make to society.

The inclusive approach is reflected in the range of organisations involved. As well as the Engineering Institutions there will be representatives from the Engineering Employers’ Federation, the Engineering and Marine Training Authority, the relevant government department, universities and industry.

The tide therefore seems to be running in the UK to submerge the profession of engineering into a much broader body, in which the ideals of professionalism seem likely to be lost. In this book we have identified the same kind of drift in Australia. There seems to be no sign of understanding in IEAust of this point, therefore these developments might be a long term portend of our future in Australia.

Community Expectations

The traditional sociological model of professional occupations implicitly provided an idealised view that imbued attitudes and approaches in the organisation and delivery of engineering education. Throughout the 20th Century engineering educationists, and the community, acted upon the belief that IEAust was an effective custodian of community interest through regulation of the formation of the profession at large in ethical values and control of ethical behaviour. However, as shown in Chapter 15, such expectations no longer are valid, even though increased individual responsibilities for work performance have made adherence to ethical principles of greater importance to the community. In the new world, social and environmental responsibility have become issues as never before for engineers as employers, employees and consultants. The legal responsibilities of corporations brought similar pressures. However, the paradigm shifts in engineering professionalism and practice discussed in Chapters 15 and 17 represent significant changes in the total system in which engineering operates. There are no obligations or restraints concerning ethical practice for the great majority of engineers, who see no relevance of IEAust, or what it shoulds stand for, in their ‘professional’ lives.

At the end of the 20th Century, while there remained an expectation in the community and by governments that all engineering professionals work on the basis of the IEAust Code of Ethics and well informed consciences in matters of community concern, the reality was different. Trust in the power of IEAust to regulate ethical behaviour had become misplaced, because it had become beyond the power and financial resources of IEAust to reach the great majority of engineers who have rejected membership. Worse than that: as discussed in Chapter 15, IEAust itself had lost sight of many of the essentials of professional life, even to the extent of seeming to set out to offend its constituency and discourage allegiance.

For the majority of engineering graduates at the end of the 20th Century, the only certain means by which they could be imbued, at least to some extent, with a social awareness, a professional ideal and an introduction to ethical principles, was through undergraduate education. However, many engineering schools have been slow to respond to a need to include studies of management, defined broadly in this way, in their undergraduate offerings.

Engineering educationists will continue to have crucial roles in maintaining the clarity of occupational identity that flows from the qualifications they confer: the benchmark BE for professional engineer and B Tech for engineering technologist. For success in any new professional body of the future, there would have to be close cooperation with the engineering schools, as the providers of education programs having appropriate emphasis upon such professional issues, together with ethics and social responsibilities. The successful design and delivery of engineering education in the 21st Century will have to be informed by an awareness of the continuing community and industry expectations of professional people in engineering. Social awareness within the engineering schools therefore will need to be enhanced in safeguarding community and individual interests.

Conclusion

The nature of engineering employment in the 21st Century will be changed for ever. Having regard to the changed professional paradigm in the globalised world: could there be a trend towards a broad and diverse 'professional' order including mixes of elements of engineering and the physical, information, biological and social sciences, with or without the traditional attributes of professional occupations? This seems to be a trend identified in the UK. Could the currently identified engineering role be subsumed
within the wider order, perhaps retaining an ‘engineering’ identity from initial education, but merging within the broader professional order? What is the implication for educationists?

Phase 4 of engineering, beginning in 2001 with the new millennium, brings the question: What are the benefits of our work? The answer requires seeing beyond design and construction to the wider societal and business context. The engineering process still has to be informed by traditional competencies imbued by key questions: What are we going to make? Can we make it? Can we sell it? Can we make a profit from it? But engineering confined to those questions would remain a closed process serving a rationalist society. A future civil society is likely to require the engineer to interact with those affected by engineering activities with additional critical questions: What is proposed to be done? What methods are involved? How are the outcomes to be put to use? Is it socially and environmentally responsible to engage in this activity? When these questions are addressed as norms of professional practice, engineering would be demystified and better attuned to the needs and aspirations of a civil society.

Looking at the future world of engineering in these terms, it is incongruous to see the IEAust taking the exclusive stance of insisting on full competency in traditional engineering design in the revised Competency Standards, rather than inclusiveness in catering for the increasing diversity of engineering practice. This, in spite of the growing understanding of the learning organisation. For engineering, the idea of the learning professional organisation in the knowledge age means a culture of broadening the horizons of educational and professional formation, a commitment to continuing professional development, and understanding and responding to the essentials of individual and collective professional lives, as exemplified by the approaches taken by APESMA.
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Appendix A  
The New Engineering Paradigm in Action

There have been several instances of crises in engineering-based organisations under the new paradigm of professional engineering practice. Much publicity has surrounded the government functions of air safety and airworthiness hitherto the responsibility of the large and very expert Federal Department of Civil Aviation, a capability now denuded of most of its professional engineering expertise and further obfuscated by confusion between Licensed Aircraft Maintenance ‘Engineers’ (who are technicians) and professional engineers. Professional engineering functions now largely are delegated to the airlines, manufacturers or consultants, or are not performed. The result has been growing public concern about air safety, frequent reports of near misses, and aircraft grounded because of faulty inspection or maintenance.

In electricity generation and supply, indications are growing in Australia and overseas of the consequences of fragmentation and artificial ‘competition’ regimes, and of strange economic models that have replaced sound engineering systems management. This whirlwind is yet to be reaped in Australia, as the downscaling of professional education in electrical power engineering is accompanied by barriers to technology transfer between ‘competing’ elements of the industry.

In this Appendix, two more specific examples of the new paradigm of professional engineering practice are presented in the form of published articles, the first on a major civil engineering infrastructure project, and the second on a private sector facility providing a vital energy infrastructure service. In reproducing these reports, no judgement is intended concerning the technical rights or wrongs of the cases. We are concerned here to highlight views concerning risks and consequences of professional engineering practice in an economic rationalist regime that inhibits opportunities for ethically placing public interest before ‘competitive economic advantage’.

In such cases, it is difficult to find one voice for the Profession of Engineering, as professional engineers are engaged in various roles in owner, contracting and government organisations. The cases quoted emphasise the difficulties that may be encountered by some professional engineers, as members of IEAust, in adhering to ethical obligations to place public health and safety before all else, and the risks that may arise for the community when other professional engineers, who reject membership of IEAust, may not be aware of such obligations.

Highlighting of text is added.

Burnley Tunnell: The Hole Truth  
Conflicting demands are behind the Burnley tunnel fiasco.

As frustrated motorists crawled around the closed and water-damaged Burnley tunnel this week, one question remained unanswered. How much did the City Link builders spend surveying the ground beneath the Yarra River before they started the big dig? Did the Transfield Obayashi joint venture follow the conventional wisdom of tunnelling that calls for 3 per cent of the contract price to go on geotechnical site exploration, or did it take the "gambler's option" and spend only 1 per cent or less?

The difference between $15 million and $5 million, engineers say, could add to the repair bills in the next few years and turn peak-hour motoring into a lottery.

Tunnels have always been difficult projects. A respected engineer says: "When you build a bridge, a dam or road, you can stand back and look at it. With a tunnel, you are forever inside the project with no way of looking at it from the outside."

For all the sophistication of modern drilling techniques, outside every tunnel the unpredictable and sometimes deadly cocktail of water, silt, mud and rock is a given. How a new tunnel withstands the pressures as the water table returns to its original level remains a balance between engineering skill and the amount of money a tunnel builder is prepared to throw at each problem. Tunnel builders follow the law of diminishing returns and calculate the money to
be spent on exploration against the alternative degrees of geotechnical certainty and uncertainty. In the gambler's option, they spend less on preparation and take a chance that the cost of repairs in the years to follow will not cripple them.

From that flows a much wider question of public safety and financial stringency. In an era of economic rationalism, have the engineers, who adhere to a code of ethics that embraces public safety, been forced to take a back seat behind the accountants?

According to one source, accountants prefer the gambler's option because it makes more sense to pay bills later rather than sooner. The savings on bank interest on borrowing for minimal exploration offer a potentially greater profit even after allowing for higher repair costs.

The forces at work here have been succinctly described by Tony Cutcliffe, a former executive director of [IEAust erroneously identified as the Institution of the Civil Engineers]: "You're conquering new frontiers, both with engineering solutions, with private capital and with the conflicting demands of companies on the stock exchange versus the private and public interest."

So sensitive is the issue that the instant water began gushing from two cracks in the wall of the Burnley tunnel on Monday morning [19 July 2001], the lid was screwed down on Australia's closely knit engineering community. Every engineer contacted except for a retired professor, refused to be identified because it would put their careers at risk. Even academic engineers, who once enjoyed complete freedom of expression, said they had to stay on the sidelines. Universities, once funded entirely by governments, now rely on paid consultancy work for a large and growing slice of their incomes.

The IEAust also ran for cover with a letter to The Age distancing itself from Tony Cutcliffe. It said he was not an employee [of IEAust] or a professional engineer and did not speak on the institution's behalf. Robert Cooper, the Victorian branch chairman, said: "The institution does not wish to comment on the current issues on the Burnley tunnel. They are extremely complex, and speculation in the media will not assist in ensuring a speedy resolution."

However, the issue of geotechnical site investigations on the Burnley tunnel has been in some expert minds for much longer than the past week. Shortly after news of the leak broke on Monday a set of technical papers and graphs was faxed to The Age that explained the comparison between the law of diminishing returns and geotechnical investigations as it relates to the City Link tunnels. One of the graphs demonstrated why a contractor might be attracted to the gambler's option. It calculated the final costs of site exploration and post construction repairs five years from the start of construction after factoring in a 5 per cent interest rate on borrowing. The graph showed that a 0.5 per cent spend on investigations with a probable higher spend on repairs was likely to end up costing $12 million, a 1 per cent spend with less repair work would probably cost $13 million, 2 per cent would reach $16 million, 2.5 per cent more than $18 million and the recommended 3 per cent would be at $20 million.

Behind the sensitivities over the tunnel lies a mountain of legal action over the delayed City Link project, which will occupy courts for up to a decade. These range from litigation over the validity of tax concessions given to the contractors, to a reputed $160 million damages action over the previous fiasco when roadway slabs lifted along a 280-metre stretch of the Burnley Tunnel and delayed its opening for months.

This latest episode promises to add to the pile of litigation between Transurban and the Transfield Obayashi joint venture. Kim Edwards, Transurban's chief executive, said: 'We will be holding the feet of the contractors to the fire to make sure that the tunnel is delivered in accordance with specifications.'

The evidence suggests that it may be a long time before the tunnel gets its final certification. Even before the latest leak, Dr Max Lay, the independent reviewer responsible for enforcing public-safety measures, was far from satisfied that the tunnel met its design specifications. When he allowed Transurban to open the tunnel to traffic in December [2000], he wrote to the City Link Authority and Transurban about unresolved issues: tolling and groundwater management. The letter said: "The facilities for ongoing groundwater management have, sensibly, not yet been designed. This is not considered to be a minor omission." Lay said these issues could be worked on while the tunnel was operating, but his letter concluded: "I do not believe that I can currently certify final completion under either the deed (the Melbourne City Link Concession deed) or the contract."

The road tunnel under the Domain has been a Melbourne dream that goes back about 40 years at least to the era of Sir Henry Bolte's long-running Liberal government in the '60s. But that administration and successive state governments came to believe such a project was too difficult and too expensive. Too difficult because the ground beneath and around the Yarra is hydrologically hostile territory. The Victorian Arts Centre subterranean build during the '70s was mined in Coode Island silt, groundwater and a pool of acid at the level of the lowest foundations. In the '90s, work on Crown Casino's foundations also were delayed by water.
The prohibitive costs of the [tunnel] project forced the Kennett government to shift the risks out of the realm of government and on to private enterprise under a BOOT (build, own, operate and transfer) scheme. Effectively, the state offered a contract to deliver to the government a fully operational road system in 2030. In the meantime, the concession holders could, within accepted limitations, make what they could out of the tunnel by tolling motorists.

The biggest infrastructure project of its era fitted perfectly with the Kennett government's private enterprise philosophies. But, according to several engineers, privatisation did more than dissipate a body of expertise developed over a long period within the state-run authorities, the State Electricity Commission, the Melbourne and Metropolitan Board of Works, the Country Roads Authority and the Melbourne Underground Rail Loop Authority. "It destroyed a culture of commitment," said one engineer this week. "When government was responsible for its infrastructure, its public utilities designed everything in exacting technical detail. Then they hired contractors to do as they were told by the experts. "When government took all the risk, accountability flowed along the chain of command through the departments and ministries to the minister. The buck stopped with the minister."

But the tunnelling arm of the Melbourne and Metropolitan Board of Works, responsible for building hundreds of kilometres of sewers under Melbourne and the Thompson tunnel in the Victorian Alps, has since been corporatised. As Project Tunnelling Australia Limited, it was sold to Transfield, one half of the Transfield Obayashi joint venture, before the tender for the City Link contract. Engineers say the old team no longer works together. Transfield's operation is much wider than the state of Victoria and its engineers have worked on tunnels around the country and overseas. Some have been lured to jobs elsewhere.

The privatisation process also broke up another board of works jewel, the ground engineering laboratory, which had a team of 50 experts, particularly soil engineers, road engineers and geologists. According to the engineer, these experts were available to provide free and unbiased opinions to government infrastructure designers. The advice was invariably free of commercial considerations because it was presumed that professional staff acted in the public interest. The laboratory, once corporatised, was sold to a private consultancy, which overnight turned the engineers into hired guns, loaned out to industry to solve problems on a fee-for-service basis without any long-term commitments. Some of these people have since left their jobs. According to the engineers, the breaking up of these two organisations has deprived City Link builders of the standard of expertise previously available to government.

The details of the 1994-95 bidding war between Transurban and its only competitor, the CHART Roads Consortium, remain cloaked behind the Kennett government's confidentiality agreements, which all bidders signed simply to look at the specifications. Former CHART members, including some of Australia's biggest engineering companies, John Holland Construction, Clough Engineering, Roche Brothers, Thiess Contractors and the German construction group Hochtief, declined to comment this week. However, sources suggest there was little difference in the bids with both groups pitching at about $1.2 billion. The choice came down to German or Japanese banking, and the state went with Australia's closest trading partners, the Japanese.

According to one engineer, spending on design becomes a critical issue in the lead-up to the tender. “This is all done in great haste with lots of corners cut. Basically, rather than government spending $5 to $10 million and 10 years investigating and designing a project, it is saying to the bidders: ‘You spend $5 to $10 million of your money. If you are successful and get the job you will get it all back. If you are not successful, you’ve done your dough.’” He said it was not surprising that bidders did not want to sink too much money into boreholes, shafts and caverns to determine how the groundwater was coursing through the cracks in the rocks.

A United States government tunnelling technology commission in 1984 recommended that expenditure on geotechnical site exploration should average 3 per cent of estimated project cost. The commission's report complained that expenditure levels at the time were too low and said the presence of groundwater was responsible for most construction problems. It added that the effects of groundwater on subsurface materials merited greater attention in exploration programs.

A paper written in 1991 by Joseph Guertin, the head of a Massachusetts tunnelling company and president of the American Underground Construction Association, showed that little or no improvement had been made in the seven years since the technology commission reported.

"The state of the art for quantitative prediction of groundwater behavior is imprecise at best," he wrote. "Design phase investigations often are either inadequately detailed with respect to groundwater control issues or are focused on other design factors." Guertin added that improper groundwater control in completed structures could create major operational,
structural and maintenance difficulties. Guertin confirmed this week that there had been no major changes to tunnel design and construction fundamentals in the past 10 years to alter this position.

The Transfield Obayashi joint venture refuses to talk about the tunnel. Transurban’s spokesman, Jeni Coutts, dismissed the issue as the work of armchair experts. "How would they know anything about it?" she said. Borrowing from a quotation from George Villiers, 2nd Duke of Buckingham, one of these "armchair experts" retorted: "They are not villains, they are not fools, they are not knaves. For good bottom-line financial reasons they appear to have adopted a gambler’s risk."

Lessons from Longford: The Esso Gas Plant Explosion
Review of Book: by Andrew Hopkins
by Athol Yates
Engineers Australia, February 2001

If you think that a disaster like the Esso Longford gas explosion could not occur at your workplace, then think again. While it may be comforting to think that the explosion and fire was due to poor training or bad luck, the reality is that there were several contributing factors which are often found in even the most safety conscious workplaces. Depressingly, some of the factors are impossible for workers, managers and even the CEO to eliminate. This is one of the important messages from the disaster expose book, Lessons from Longord. Written by Dr Andrew Hopkins, sociologist at the Australian National University in Canberra, the book examines the organisational reasons for the 1998 disaster that killed two, injured eight others and cut Melbourne’s gas supply for two weeks.

In doing so, it lays bare the workplace’s degraded systems, its lack of safety control and uninformed staff and operators at the time.

The book only briefly touches on the technical causes of the explosion. It happened when 230°C oil entered a frozen pressure vessel as the plant was restarted after a minor problem. The vessel’s metal had become brittle and cracked, volatile liquid and gas escaped, and a nearby spark ignited the hydrocarbon cloud. The Royal Commission report mainly focused on direct causes of the explosion, such as operator error, lack of training and poor safety systems.

The merit in Hopkins’ book is that it climbs further up the chain of causes. This approach takes the reader through the full range of contributing factors, such as management system inadequacies, regulatory failures and even the cost cutting pressure driven by the need to meet share holder dividend demands. The principle behind this analysis is that if the organisational factors are right, the technical causes of accidents will not come into play.

The book brings into question much so-called business wisdom such as competency-based training (CBT), decentralisation of safety and self-regulation. CBT has been embraced internationally as the best-practice approach to vocational education and training. It consists of developing training modules which result in someone gaining the knowledge, skills, and abilities required to perform a certain job. Despite the appealing sound of CBT, its application in many work places resulted in the atomisation of work functions producing a set of trivial skills, to teach only those tasks defined in competency outcomes, and to provide only the minimum knowledge needed to undertake a task.

This problem can be seen at Esso which ran a degenerated form of CBT. Hopkins describes the company’s training approach as one which identified the specific knowledge which operators required to do their job, provided them with this information and tested whether they could present this information back to an assessor. It did not test for understanding.

He offers an alternative approach of providing operators with an understanding of the fundamental scientific or engineering principles involved. Such an approach would give operators considerably more knowledge than was required for routine plant operations but would make them better able to analyse and deal with non-routine occurrences.

Another management sacred cow under Hopkins’ gaze is the decentralisation of safety. Conventional wisdom is that those closest to the workplace are in the best position to manage their own safety. This may be true for eliminating common hazards such as slippery surfaces and dangerous machines. These are the easy ones to spot. However, as the explosion indicated, decentralisation of safety is inadequate to prevent the rare but catastrophic events. These are the ones which require experience to know what to look for and to spot the warning signs.

Historically these low frequency, high consequence risks were managed by a safety section at head office. These staff would oversee a number of plants and ensure that the lessons learned about rare
events were passed around. Information on the rare catastrophic brittle failure of pressure vessels should have been known by Esso as it was available from their parent company, Exxon. In 1974 and 1983, researchers from Exxon Research and Engineering Company published warning articles on these failures. As a direct result, Exxon had inserted into their hazard identification guidelines the requirements that special attention be paid to the possibility of brittle fracture. Unfortunately, Esso’s most senior manager in charge of risk assessment was not aware of the two articles nor was Esso’s general manager aware of the brittle fracture warning in the guidelines.

**According to Hopkins, the lesson here is that downsizing of central safety staff and the decentralisation of safety may have gone too far.** What is needed is a balance between central oversight and local control.

Public disasters often lead to the reestablishment of oversight. An example of this is in government contracting. This decade has witnessed a rapid decentralisation of authority to sign government contracts and the consequences of this are coming home to roost politically. Last September [2000], the ACT’s chief minister resigned as a direct result of the contracting fiasco surrounding the $45 million Bruce Stadium redevelopment. As a result of this and other instances where there was a lack of central and informed oversight, the ACT government has reversed its decentralised approach to contract management. It has now established a new accreditation unit which will accredit ACT government agencies to undertake their own procurement only if they can demonstrate they are competent to do so.

Industry self-regulation has become another mantra of modern business practice, but, in Esso’s case, this has not resulted in the expected outcomes. Far from resulting in safety best practice, self-regulation allowed Esso to fall considerably short of best practice, according to the Royal Commission. Best practice hazard identification would have involved carrying out a hazard study of gas plant. Esso did not carry it out and defended itself by arguing that it was not required to do so either by law or under Exxon’s own guidelines.

Self-regulation allowed a system to develop where staff used to operate the plant outside specified limits, with warning alarms constantly ringing, as this was the easiest way to maintain the quality of the outgoing gas. It allowed a safety environment to operate where 300 alarms on average went off each day with one incident causing 8500 alarms to trip or 12 every minute over a 12 hour shift. This environment desensitised operators to all alarms.

A major contributing factor to the situation arising at Longford was the failure of government to ensure that Esso provided a safe workplace. This was because the government gutted the agency which has this function, Work Cover. The government saw that the shift from prescriptive regulation to self-regulation meant that certain work was no longer needed, such as sending inspectors to companies to identify breaches of prescriptive rules and regulations.

Consequently staff were shed.

The lesson in this is that self-regulation can rapidly degenerate into deregulation if there is no enforcement of the new system.

There are a number of other really big issues raised in Hopkins’ book. These include the often mistaken belief that someone is actually in charge of highly automated systems, the failure of bad news to be passed up the management chain, and the fact that management often has little understanding of what is happening at the shop floor level.

The identification of these points is what makes Hopkins’ book so useful. It is a tragedy that the cost of discovering then was so high. Companies should invite Hopkins, the Royal Commissioners and other experts to their workplaces to examine the lessons as a first step to preventing the rare but catastrophic disasters.

**Athol Yates is senior policy analyst at the IEAust's National Office in Canberra. The IEAust is currently undertaking a study of Australia's petrochemical industry to determine if the industry has implemented measures in response to the lessons learnt from the Longford explosion.**
Appendix B

The Balance Between Engineering and Science Faculties in Australia, Singapore and the Republic of China (Taipei)

By Michael R Rice

Introduction

As discussed in Chapters 14 and 16, Australia's higher educational system differs from those of many countries in that, in the technical fields of study, that is engineering and science, the emphasis here is placed on science. As a result, relative to population Australia graduates more persons with bachelor degrees in science and information science than any other country.

Although this is not generally recognised, the consequence is that the distribution of Australian research and development expenditure between engineering and science is markedly different from that of nations such as the Republic of China and Singapore and many other nations with which Australia often is compared.

University Graduates

Singapore

There is one country places more emphasis on engineering education than any other. That country is Singapore. In relation to the education of engineers and scientists Singapore could well be considered to be the mirror image of Australia. Only a small proportion of university graduates complete studies in the natural sciences, whether at the undergraduate level or the post graduate level. Not only is the annual number of graduations in science comparatively small but the number of natural science graduates at bachelor degree level has increased only by 14 per cent between 1993 and 1999. In contrast the number of engineering graduates has increased by 54 per cent over the same period.

The levels of undergraduate enrolments in both fields indicate that over the next three years the ratio of engineering graduates to science graduates will continue to increase. On the basis of enrolment trends, it may be anticipated that the number of persons completing science degrees might increase by only 7 per cent, while new engineers are likely to increase by 40 per cent or more. Undergraduate enrolments in engineering have increased from 30 per cent of total undergraduate enrolments in 1993 to 41 per cent in 1999. Undergraduate enrolments in natural science represented 10 per cent of all undergraduate enrolments in 1993, but by 1999 the proportion declined slightly to 9 per cent of all undergraduates. The number of completions of higher degrees in engineering has increased at least six-fold over the period 1993 to 1999, and is now over five times the number completing higher degrees in the natural sciences.

The relative enrolment data indicates that this ratio is likely to persist over the next few years. It may be anticipated that completions in engineering higher degrees will display continuing vigorous increases in the next four years. The proportion of enrolments in higher degree courses in engineering has increased from 34 per cent of all higher degree enrolments in 1994 to 44 per cent of enrolments in 1999. The proportion of enrolments in higher degree courses in the natural sciences has declined from 8 per cent in 1994 to 7 per cent in 1999.

Republic of China (Taipei)

The Republic of China (ROC) also devotes considerable resources to engineering education. In 1997, 29 per cent of all undergraduate completions were in the engineering field of study. In contrast only 12 per cent of bachelor degree graduations were in the natural science fields.

In the case of higher degrees a similar emphasis is placed on engineering. Nearly 35 per cent of all master degrees were granted to engineering graduates in 1997. In the case of the natural sciences 9 per cent of all master degrees were awarded in that field of study. Similarly, 36 per cent of all doctoral degrees awarded in 1997 were in engineering whereas only 14 per cent of doctoral degrees were awarded in the natural sciences. The degree of emphasis the ROC places on engineering education is exemplified by the fact that over the period 1992 to 1997 the annual number of engineering graduates increased by 36 per cent while over the period 1993 to 1997 the number of bachelor level degrees in the natural sciences increased by only 6 per cent.

In the case of master degrees similar high rates of growth occurred in the engineering field while the number of master degrees in the natural sciences rose at a somewhat slower pace. In the case of doctoral degrees the rate of growth of the annual number of awards was, if not identical, fairly similar for the two fields of study.

Australia

The difference between Australia and these two countries is immediately evident when the relative balance between engineering and science enrolments in the three countries is examined. In 1999, total bachelor degree enrolments by Australians in science, including information technology, represented 18 per cent of all bachelor degree enrolments. In contrast, enrolments in engineering represented 8 per cent of total enrolments.

It should be noted that published Australian educational statistics the science field of study includes both the natural sciences and information technology. It can be reasonably assumed that natural science represents about two-thirds of the number of students in the science field of study. Therefore, while there can be no direct comparability be-
tween the Australian data for science and the data for natural science in Singapore and the ROC, the comparisons between the countries may be taken as being reasonably indicative of the relative educational emphasis that exists. Even if only fifty per cent of Australian science graduates completed degrees in the natural sciences, relative to population Australia would still lead the world in the bachelor degree completions in the natural sciences.

In the case of higher degrees, Australian enrolments in science represented 14 per cent of all higher degree students, whereas engineering enrolments were 7 per cent of total enrolments. For the purposes of this analysis only, to maintain consistency with the analysis of the enrolments in the two Asian countries, only master and doctoral level degrees have been considered, and graduate diplomas have been ignored.

In 1998, the pattern of bachelor degree completions in Australia was somewhat similar to that indicated by the data for total enrolments. Completions from engineering courses were equivalent to 6 per cent of all completions, whereas science completions represented 17 per cent.

At the undergraduate level, in Australia there are over three science graduates for every engineering graduate, in Singapore there are approximately 60 per cent more engineering degrees awarded than for science. The indications are Singapore soon will produce three engineering graduates for every science graduate.

At the post-graduate level in Australia, engineering graduates and science graduates represented 7 and 13 per cent of higher degrees respectively.

The relative weight given to engineering and science studies is emphasised by the relative growth rates of the number of commencements in each field. At both the undergraduate and post-graduate levels, science has done better than engineering. Undergraduate commencements in engineering have increased only by 11 per cent between 1993 and 1999. On present indications the number of engineering graduates is not likely to grow above current levels in the next few years. Commencements in science courses have increased 35 per cent over the same period. Recent enrolment trends indicate that the number of graduates is likely to increase substantially over the next few years.

At the post-graduate level engineering commencements have declined 19 per cent between 1993 and 1999. Postgraduate commencements in the science field of study have increased by 31 per cent over the same period.

**Conclusion**

The foregoing comparisons indicate that, while the two Asian nations have focused their principal educational effort on engineering education, Australia has placed the emphasis on science education. Not only are the relative patterns of education entirely different, but the consequences for the development of qualified manpower differ quite substantially.

Australia leads the world in terms of the annual number of science graduates per million population but trails most countries of the world in the relative number of engineering graduates.

The ROC and Singapore educate natural scientists at a level approximately equivalent to the average for industrial nations but are, along with Japan, Korea and Finland, in the top six nations in terms of the level of engineering graduations relative to population. There are obvious consequences for the distribution of research and development effort between the sciences and engineering.

**Research and Development Expenditure**

It would be reasonable to expect that there would be a rough proportionality between the number of students and the number of academic staff in any technical field of study in a higher education institution. Because one of the major roles of academic staff, apart from teaching, is performance of research, it would also be reasonable to expect a rough proportionality to carry across to the levels of research in the natural science and the engineering fields of study.

The following table demonstrates that the level of R&D expenditure in these fields in certain countries does tend to be related, albeit only crudely. Unfortunately, the data relating to the distribution of R&D expenditure in the higher education sector of Singapore was not available but the relativity between the levels of engineering and natural science R&D expenditure is very likely to be predominantly in favour the engineering field of study.

It is readily apparent from the table that:

1. The Asian nations all placed an emphasis on engineering education.
2. The relative levels of expenditure reflected the relative numbers of graduates.
3. Both the ROC and Japan expend a considerably greater proportion of GDP on engineering R&D in their higher education sectors than does Australia. It is likely that Singapore does the same.

In discussions of Australia's R&D effort it is frequently maintained that we should imitate such nations as Singapore, Korea, Finland or Ireland thus increase our expenditure on R&D in the higher education sector. Such comments ignore certain realities. The first of these is that all but one of these of these countries, Finland, expend a smaller proportion of their GDP on R&D in the higher education section than does Australia. The second is that, with the exception of Ireland, the pattern of education in these countries places considerable emphasis on engineering education. Thus, it is very likely that the pattern of R&D expenditure in the higher education sector reflects this distribution of effort. In the case of the ROC we know this to be so.
Conclusion
As in the case of education, it is readily apparent that, relative to the level of R&D in the higher education sector of at least some of the countries with which Australia is compared, engineering research in the Australian higher education sector is at a low level. In contrast the level of R&D expenditure in the natural sciences in Australia is comparatively high.

One wonders whether in urging the Australian government to emulate such countries as Singapore the leaders of the higher education lobby groups realise that they are advocating a marked expansion of engineering education in Australia.

An examination of R&D expenditure in the government sectors of the other countries discussed demonstrates that, once again, the successful exporting nations of Asia devote a greater level of their national R&D effort to engineering research in the government sector than does Australia.

That these issues are ignored by Australian commentators on research policy leads one to question the quality of much that passes for informed comment on R&D Policy in Australia.

<table>
<thead>
<tr>
<th>Country</th>
<th>Year</th>
<th>Science graduates as a proportion of engineering graduates (per cent)</th>
<th>Annual expenditure on R&amp;D in the natural sciences as a proportion of engineering R&amp;D expenditure (per cent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Japan</td>
<td>1995</td>
<td>100</td>
<td>19.5</td>
</tr>
<tr>
<td>Republic of China</td>
<td>1997</td>
<td>100</td>
<td>26.9</td>
</tr>
<tr>
<td>Singapore</td>
<td>1999</td>
<td>100</td>
<td>35.6.</td>
</tr>
<tr>
<td>Australia</td>
<td>1998</td>
<td>100</td>
<td>244.4</td>
</tr>
</tbody>
</table>

Notes:
(a) The data for R&D in the Australian higher education sector are in error to an unknown extent because of deficiencies in the classification of fields of research that was used in the surveys of R&D expenditure up to and including 1998. As a result of these problems the stated level of engineering R&D is an overestimate and the level of R&D in the natural sciences is an underestimate.
(b) The total number of graduates includes both first degrees and higher degrees.

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