

## MANAGEMENT EDUCATION IN AUSTRALIAN ENGINEERING UNDERGRADUATE COURSES

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### Abstract

In response to a perceived need for management studies in engineering undergraduate courses, the Institution of Engineers, Australia (IEAust) mandated a requirement that 10% of course content be management studies in Australia in 1991. Although support for the 10% rule was not universal, a 1994 national report on engineering education found "strong endorsement" for the policy. In 1996 a major review of engineering education in Australia recommended that IEAust move from a course accreditation regime based on prescribed inputs to one based on demonstrated graduate attributes. In the move to the new accreditation system, the policy on management studies in engineering undergraduate courses has become less definitive and more open to interpretation by individual educational institutions. Recent research on Australian academics involved in management studies in engineering undergraduate programs has revealed that while more than 95% hold technical qualifications, more than 60% hold no management qualification at all. These results and others presented here provide insight into the backgrounds, beliefs, qualifications, and experience of the academic staff involved in management education in engineering undergraduate courses in Australia.

### Introduction

In 1991, Young reported in *Engineering Management Journal* on the historical developments in Australia that culminated in a mandate by the Institution of Engineers, Australia (IEAust), the accrediting body for engineering undergraduate courses, that courses contain at least 5% management content by January 1991, rising to "about 10%" by 1995 (Young, 1991). Since that time there have been a number of significant developments in engineering management in Australia that have influenced undergraduate management studies. This article summarizes those developments and their impacts on management education in engineering undergraduate courses, reports on recent research on engineering management education in Australia, and outlines likely future developments in Australia.

### Historical Developments

Australia has a population of approximately 18.9 million persons (estimate for June 1999), of whom approximately 98,000 are employed as professional engineers (estimate for 1999). 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. (Lloyd, 1968)

A 1972 survey of 1426 practicing Australian engineers found that 92% of respondents indicated that management studies should be included at the undergraduate level (PE Consulting Group [Australia] Pty. Ltd., 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 IEAust's National Committee on Engineering Management to introduce a mandatory component of management studies into undergraduate courses did not succeed (Young, 1991). The 1988 Australian government discipline review of engineering education surveyed both final-year students and graduates and found that the course areas with the greatest discrepancy between required and actual emphasis were development of self-confidence and an understanding of motivation, industrial relations/management of people, engineering as part of the broader business context, management of costs and resources, and oral communication skills (Williams, 1988).

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

### About the Author

**Stuart Palmer, C.P.Eng.**, studied electronics engineering at Ballarat College of Advanced Education, graduating in 1986. Between 1987 and 1994, he worked with a consulting engineering firm in electronic design, industrial automation, and process control, progressing from project engineer to senior engineer to business unit manager. In that time he also completed an MBA in technology management. In 1995, he joined the school of engineering and technology at Deakin University, where he holds the position of senior lecturer, lecturing in technology management at the undergraduate and postgraduate levels. He is currently engaged in doctoral studies, and his research interests include engineering education, the use of new media in education, and the relationship between technology and society.

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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. (Institution of Engineers, Australia, 1991)

It should be noted that this policy was not greeted with unanimous support by engineering schools around Australia, and that after nine years, the level of compliance with the 10% rule still varies significantly: 36% of Australian engineering schools meet or exceed the 10% requirement, 36% nearly meet the requirement (8 to 9%), and the remaining 28% fall significantly short of the 10% requirement.

**Developments During the 1990s.** By 1991, the Task Force on Engineering Management had spawned the Society for Engineering Management Australia, which continues to this day as a technical society of IEAust. The first meeting of the Australasian Conference of Engineering Management Educators (ACEME) took place in 1992, and has continued as an annual meeting of engineering management educators and practitioners in Australia and New Zealand, with international visitors. ACEME has been a valuable forum for networking and exchange of ideas relating to engineering management education.

The year 1992 also saw the publication of the report entitled *Skills for the Future—Engineers and Scientists Achieving Enterprise Performance*, which was jointly prepared by the Association of Professional Engineers and Scientists, Australia; the Australian government Department of Employment, Education and Training; 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 in its managerial and business dimensions. (Bates et al., 1992)

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 [sic] a pressing imperative for most engineering graduates as soon as they join the workforce. (Bates et al., 1992)

In 1993, IEAust released its *National Competency Standards for Professional Engineers*. This document sought to "identify the overall balance of knowledge, skills, judgement, ethical standards and experience required by Professional Engineers" (Institution of Engineers, Australia, 1993). In the *Standards*, these objectives were achieved by defining 11 units of competency, which were divided into elements of competency, which were further divided into performance criteria. These 11 identified units of competency included professional engineering ethics and principles, management, and communication.

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

In 1994, the Department of Employment, Education and Training commissioned the *Report on the Impact of the Discipline Review of Engineering*. The inquiry's aim was to determine the impact of the recommendations of the 1988 Williams review. The inquiry noted that there was "quite strong" endorsement for the 1991 IEAust policy for management education in undergraduate engineering courses, particularly for the requirement of 10% management content in courses (Caldwell, 1994).

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

In response to the review's recommendations, 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. (Institution of Engineers, Australia, 1997)

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

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

...integrated exposure to professional engineering practice, including management and professional ethics (about 10%). (Institution of Engineers, Australia, 1999a)

In early 1998, IEAust undertook a review of its competency standards, and the second edition was published in April 1999.

The new edition is more comprehensive than its predecessor, with the competency standards for professional engineer, engineering technologist, and engineering officer included in a single volume. While the new edition still contains references to management competencies for professional engineers, competencies such as business management, project management, and engineering operations are now classified as "elective," and the "core" competencies for professional engineers have been reduced to "practice," "design," and "self-management" (Institution of Engineers, Australia, 1999b).

### Australian Engineering Management Academics

While policy from the course accreditation body and other related stakeholder organizations 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 charged with the responsibility for the design and conduct of these studies. To gain an appreciation of the backgrounds, beliefs, qualifications, and experience of engineering management academics in Australia, I conducted a survey of this group in 1998.

At the time of the survey, 93 separate academic units (faculties, departments, schools) were found to be offering one or more undergraduate engineering courses in Australia. The heads of all of these academic units were contacted with the request that they nominate appropriate staff members (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) to receive the survey. Responses were received from 59 of the identified academic units—a response rate of 63.4%. The list of nominated recipients was supplemented by identifying other Australian academics actively publishing in the field; sources consulted included all recent conference proceedings of the Australasian Association for Engineering Education, the UNESCO International Center for Engineering Education, and ACEME. A

total of 146 potential participants were identified and were sent the survey via post. Responses were received from 57 participants. Of these 57 respondents, 16 indicated that they were "not the appropriate person" to complete the survey—more than 10% of potential respondents had been inappropriately identified by the head of their academic unit! The remainder of valid responses was 41, or 28.1% of the identified qualified potential respondents.

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. Males accounted for 87.8% of respondents, while 12.2% were female.

Exhibit 1 shows the percentage of respondents holding a technical qualification. Note that in Australia, a diploma qualification represents a sub-bachelor award; for example, in engineering, a bachelor of engineering is a 4-year award, and a diploma of engineering was a 3-year award that existed prior to 1980. A graduate diploma is a post-bachelor award, normally by coursework, taken to broaden or deepen the experience of the candidate. Exhibit 1 also shows the distribution of technical qualifications found in the general population of Australian engineering academics (Anderson et al., 1997), which does not depart significantly from that of the respondent group, as well as the percentage of respondents holding a management qualification. It reveals that more than 60% of 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 cause for concern. While experience of the practice of engineering management is valuable in contextualizing management studies, academic rigor in the discipline area should be considered a fundamental prerequisite for those in educational roles. Exhibit 2 summarizes the years of experience of respondents working in the engineering workforce, in a management capacity, and in a lecturing/teaching capacity. The median values reported demonstrate significant practical experience in technical, management, and educational areas.

**Exhibit 1.** Percentage of respondents holding technical or management qualification and percentage of Australian engineering academics with technical qualification

Qualification	% of respondents with the following qualification:		% of Australian engineering academics with a technical qualification
	Management	Technical	
No degree	61.0	4.9	NA <sup>1</sup>
Diploma	0.0	2.4	NA
Bachelor	12.2	14.6	9.5
Graduate diploma	9.8	2.4	NA
Master	12.2	19.5	18.2
Doctorate	4.9	56.1	68.0
Other	NA	NA	4.3

<sup>1</sup>NA, not applicable.

**Exhibit 2.** Years of experience of respondents working in engineering, management, and education

Field	Parameter <sup>1</sup> (years)				
	Mean	SD	Min.	Max.	Median
Engineering	14.3	13.5	0	54	10
Management	10	8.9	0	40	8
Education	11.7	8.7	0.25	35	9

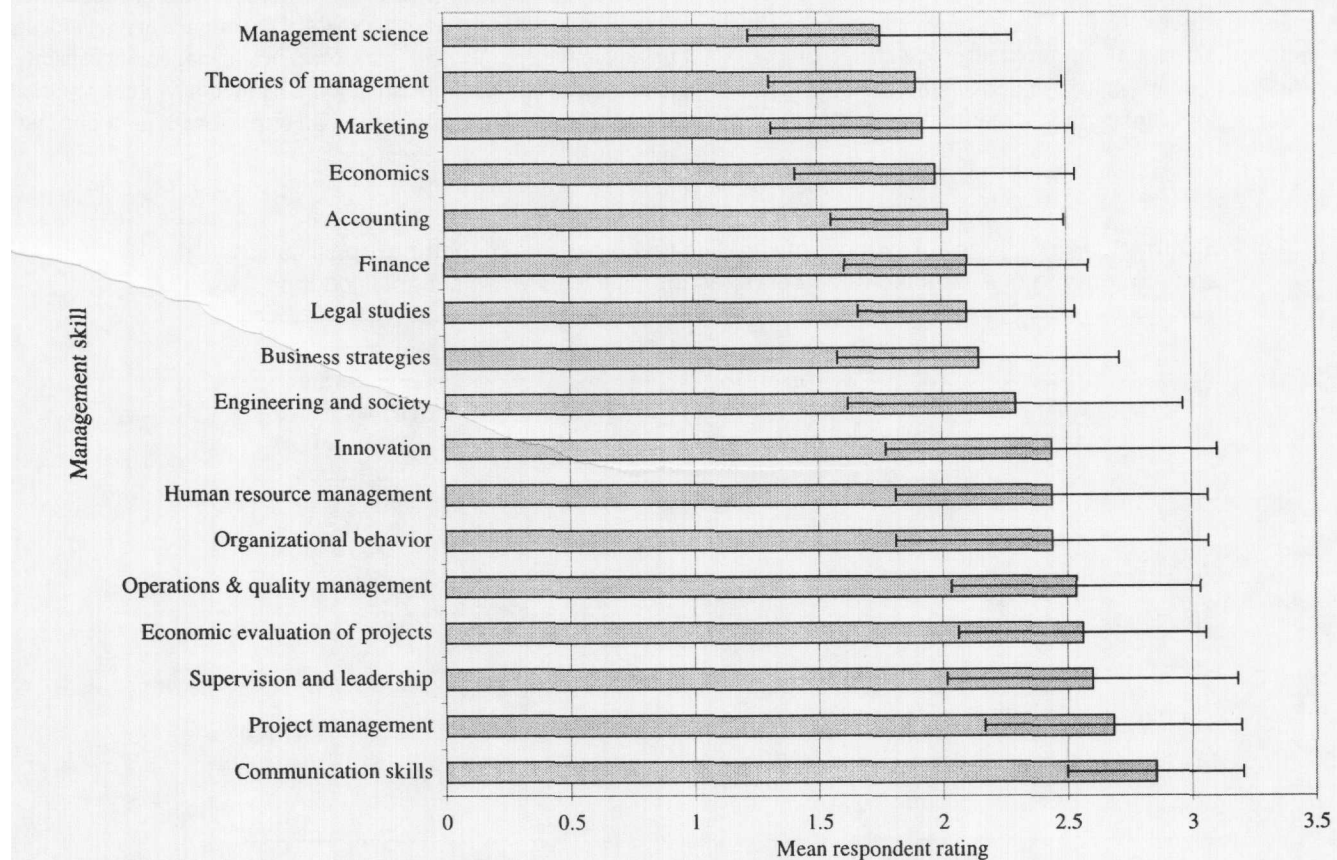
<sup>1</sup>SD, standard deviation; Min., minimum; Max., maximum.

The 1991 IEAust document *Guidelines for Management Studies in Engineering Undergraduate Courses* provides a model undergraduate engineering management curriculum composed of 17 modules of study. This model curriculum has been presented previously in *Engineering Management Journal* (Young, 1991). Respondents were asked to rate the importance of each of these 17 elements on a 3-point scale. Exhibit 3 shows the results, including the mean response and the standard deviation for each of the 17 elements.

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. It appears that these skills are identified either as being "part of engineering" (i.e., project management, operations and quality management, and economic evaluation of projects) or as important generic professional practice skills (i.e., communication skills, and supervision and leadership). These five elements are highly practical, action-oriented activities that members of the engineering workforce may be involved in on a regular basis.

Support was less strong and/or more equivocal for the remaining skills. Following the five highest-ranked elements, in order of decreasing mean rating, were organizational behavior, human resource management, innovation, engineering and society,

**Exhibit 3.** Perceived importance of management skills<sup>1</sup>

<sup>1</sup>Respondents used a 3-point scale: 1 = not important, 2 = important, and 3 = very important.

business strategies, legal studies, finance, accounting, economics, marketing, theories of management, and management science. It is possible that the lower rating of these particular management skills is due either to the more theoretical nature of the topics (e.g., organizational behavior, management science, etc.) or to their close identification with other (non-engineering) professions/business functions (e.g., legal studies, marketing, accounting, etc.).

Respondents were 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 Exhibit 4. 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.

When asked "whether the most important phase for engineering management education was undergraduate, postgraduate or both," 12.5% of respondents answered that the undergraduate phase was the most important, 12.5% indicated that the postgraduate phase was the most important, and 75% said that both phases were important. Thus, almost 90% of respondents indicated their belief that engineering management education should be included in undergraduate studies.

#### Future Directions

It is clear that the final versions of IEAust's 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 "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 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 depend largely on the belief of those responsible for course design in the importance of management studies for engineering students.

In my opinion, 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 30 years of work in promoting the importance of preparing engineering undergraduates to appreciate the central role that management plays in professional engineering practice, and in binding together all the elements of the engineering process.

It is noted that the recently released final version of IEAust's *Manual for the Accreditation of Professional Engineering Programs* contains the statement that universities seeking

**Exhibit 4.** Other management skills identified as important

Management skill (no. of respondents)	
Time management (5)	R&D management (1)
Teamwork (3)	System dynamics (1)
Technology management (3)	Information technology (1)
International business (3)	Systems approach (1)
Industrial relations (3)	Public relations (1)
Cross-discipline interaction (2)	Maintenance management (1)
Ethics (2)	Environmental management (1)
Decision making (2)	Strategic management (1)
People skills (2)	Cost estimating (1)
Change management (2)	Risk management (1)
Lifelong learning (2)	Media relations (1)
Networking (1)	Management of design (1)
Supply management (1)	Contract management (1)
Dealing with customers (1)	Cost control (1)
Negotiation (1)	Cybernetics (1)
Logic (1)	Report writing (1)
Problem definition (1)	Forecasting (1)

accreditation of professional engineering courses will be required to have in place a quality management system that encompasses, among 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. (Institution of Engineers, Australia, 1999a)

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.

### Discussion

Recent international reviews of engineering education reaffirm 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)

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.). (Working Group on Lifelong Learning and Continuing Education in Engineering, 1998)

Various Australian reviews and reports on engineering education (some of which are identified above) have reached the same conclusion. Australia's 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 a loss of focus on the issue of engineering management studies for undergraduates in Australia, and for its passing to go largely unremarked upon.

One clear indication that management skills remain crucial for engineers after graduation is in the number of engineers who 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 it accounts for 25% of all MBA enrollments in Australia. 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 results presented in Exhibit 1 indicate that while more than 86% of Australian engineering academics hold a technical qualification of master level or greater (Anderson et al., 1997), about 17% of the Australian academics involved in undergraduate engineering management education who participated in this survey 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 (employed by many engineering schools) for injecting academic rigor, 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. Many students come to engineering studies with little appreciation of the role that management will play in their long-term careers. Management studies that are not presented in an engineering context will only prolong this ignorance. Any temptation to completely hand over the teaching of management studies in undergraduate engineering courses to staff from management/business faculties should be resisted, as these staff may have difficulty in presenting examples of the application of management principles in the context of real engineering practice.

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