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

INTRODUCTION

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

HISTORICAL DEVELOPMENTS

As far back as 1968 it was identified that:

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

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

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

industrial relations / management of people, engineering as part of the broader business context, the management of costs and resources, and oral communication skills [5].

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

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

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

DEVELOPMENTS DURING THE 1990s

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

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

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

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

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

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

- professional engineering ethics and principles;
- management; and

- communication.

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

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

RECENT DEVELOPMENTS

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

In response to the recommendations of the review the IEAust issued a revised framework for the accreditation of undergraduate courses in 1997. The new policy on

the accreditation of professional engineering courses contained the following revised course content requirement relating to engineering management:

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

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

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

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

> *"...integrated exposure to professional engineering practice (including management and professional ethics). This element should be <u>about</u> 10% of total program content;"* [14].

In early 1998 the IEAust undertook a review of its competency standards, the second edition being published in April 1999. The new edition is more comprehensive than its predecessor, with the competency standards for professional engineer, engineering technologist and engineering officer included in a single volume. While the new edition still contains references to management competencies for professional engineers,

competencies such as business management, project management and engineering operations are now classified as ‘elective’, and the ‘core’ competencies for professional engineers have been reduced to ‘practice’, ‘design’ and ‘self-management’[15].

FUTURE DIRECTIONS

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

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

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

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

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

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

WHAT CONSTITUTES AN ENGINEERING MANAGEMENT STUDIES SYLLABUS?

Just as an engineering school has to devise an overall curriculum for a course of studies, it must also develop a sensible, integrated and coherent syllabus for an engineering management stream within its courses. In the past, clear guidance was provided by the IEAust through its course accreditation requirements which referenced its Guidelines for Management Studies in Engineering Undergraduate Courses [6], and more broadly through its National Competency Standards for Professional Engineers. Even though the

Guidelines were quite detailed, providing a rationale for management studies in undergraduate engineering courses, suggesting a model study structure comprising 17 units of management studies, and suggested contents for each of the units, they were clearly prefaced with the rider that they were not intended to be prescriptive, and that each school should devise their own approaches and subject arrangements. The Guidelines, while no longer referenced as part of the current formal IEAust accreditation process, still provide valuable direction as to what constitutes an engineering management studies syllabus for undergraduate programs.

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

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

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

SURVEY OF RECENT DEAKIN ENGINEERING AND TECHNOLOGY GRADUATES

Context

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

Methodology

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

- demographic information — age; gender; study mode;
- experience in engineering practice;
- experience in management roles;
- identifying management skills that had been important in practice; and

- evaluating the effectiveness of the management stream in the Deakin undergraduate engineering program.

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

Table 1 - Management skills inventory used by survey respondents

Results

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

The employment sectors reported by the respondents covered a wide range, including public sector, private industry, manufacturing, IT, consulting, building, education and

postgraduate studies. The job functions reported by the respondents covered a wide range, including director, lecturer, manager, designer, project manager and research and development. The range of specific management roles reported as held by respondents is given in table 2.

Table 2 - Management roles reported as held by respondents

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

Figure 1 - Importance of management skills as identified by respondents

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

Table 3 - Respondent evaluation of effectiveness of undergraduate management studies

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

Table 4 - Improvements to management studies suggested by respondents

Outcomes

The fact that 12.6% of the originally targeted recent graduates were no longer at the most recent address recorded for them highlights the difficulty in maintaining contact with students once they leave the university. The gender and graduating discipline proportions of the target potential respondent group were known, permitting a comparison with the actual respondent population. The proportion of female students in the target group was 16.3%, this was not significantly different from the respondent group ($\chi^2_1=0.469,\ p>0.49$). The graduating discipline proportions of the target group were Manufacturing = 54.8%, Environmental = 20.7%, and Mechatronics = 24.4%, this was not significantly different from the respondent group ($\chi^2_2=0.886,\ p>0.64$). This suggests that actual respondent population is a representative sample of the target potential respondent group.

The most frequently reported management skills (reported as important by 40% of respondents or more) include *communication skills*, *project management*, *time management*, *supervision and leadership*, *teamwork*, *decision making*, *project evaluation*, *cost estimation*, *occupational health and safety*, *report writing* and *dealing with customers*. These first eleven skills are all important generic professional practice skills that highly practical, action-oriented activities that members of the engineering

workforce are likely to be involved in on a regular basis. The survey reveals that these skills are important even to recent graduates.

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

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

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

DISCUSSION

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

> *"It is clearly recognized that many engineers progress into managerial and top executive positions in industry and government. For such individuals the foundation should be laid in college for an understanding of human relationships, the principles of economics and government, and other fields upon which the engineering manager can build."* [19];
>
> *"Engineering Faculties should:...emphasize design, problem solving, the impact of engineering on society and the environment, communication, teamwork, leadership and practical experience..."* [20];
>
> *"The real world is not as precisely defined as technical courses at school and university would lead students to believe...The varied problems that arise in daily professional life are not so restricted. They demand varied responses, with an integration of insights brought to bear from many different perspectives (technical, manufacturing, psychological, marketing, historical, economic, etc.)."* [21].

Various Australian reviews and reports into engineering education (some of which are identified above) have reached the same conclusion. One clear indication that management skills remain crucial for engineers post graduation is the number of engineers that seek postgraduate studies in management. In the United Kingdom 32% of

MBA students are engineering graduates [22]. In Australia the largest MBA program is one designed principally for engineers and focussed on the management of technology [23].

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

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

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Table 1 - Management skills inventory used by survey respondents

Communication skills	Project management	Legal / law
Supervision & leadership	Accounting & finance	Economics
Quality management	Professional ethics	Marketing
Organisational behaviour	Operations management	Business strategies
Project evaluation	Human resource manage.	Theories of management
Teamwork	Lifelong learning	Systems approach
Time management	Public relations	Maintenance management
International business	Strategic management	Cost estimation
Risk management	Environmental manage.	Industrial relations
Design management	Supply management	Change management
Dealing with customers	Decision making	Negotiation
Report writing	Contract management	Forecasting
Motivation	Competition	Conflict resolution
Occupat. health & safety	Creativity	Information management
Logistics	Inventory management	Work/time study

Table 2 - Management roles reported as held by respondents

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

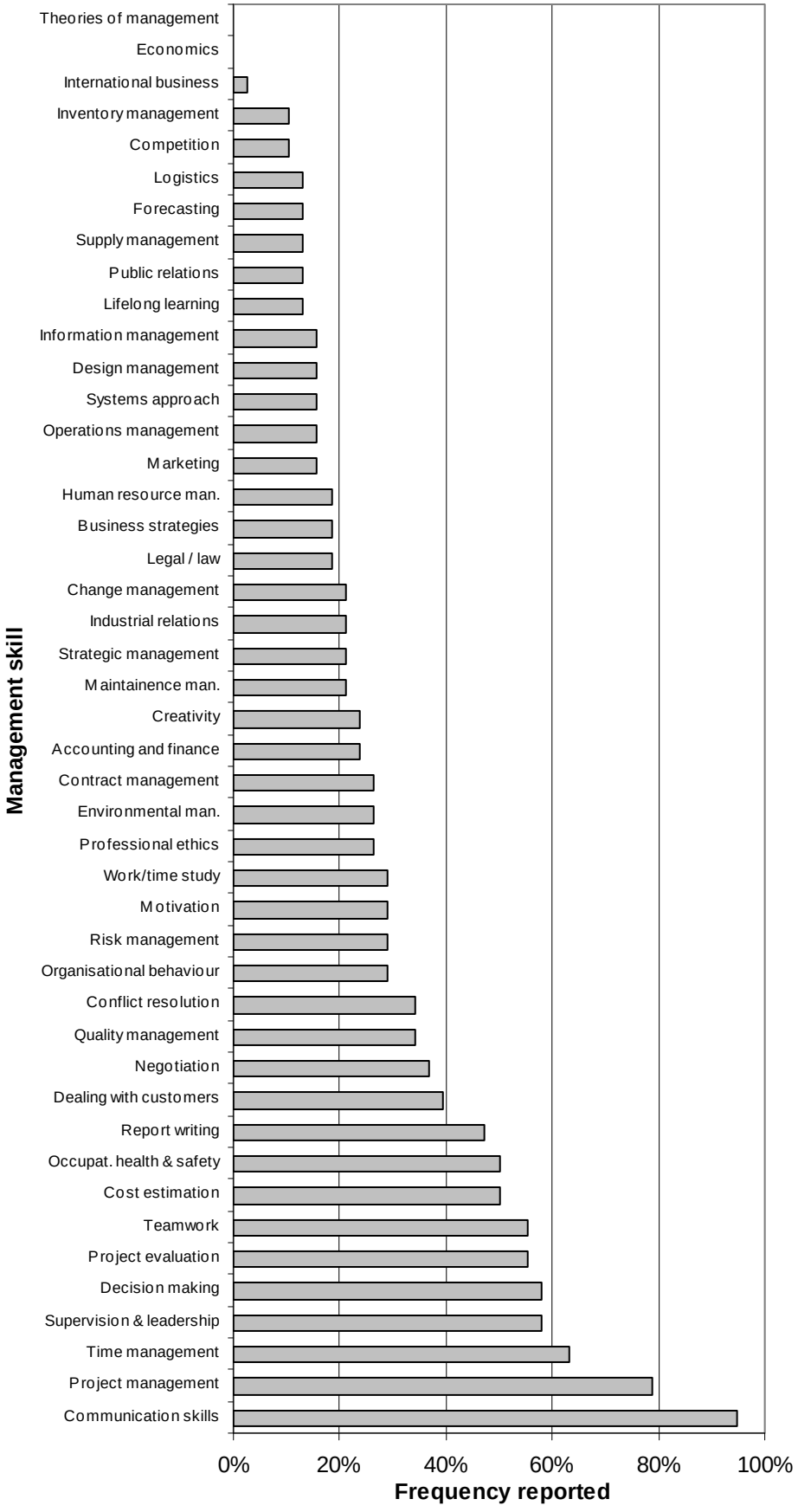

Figure 1 - Importance of management skills as identified by respondents

Table 3 - Respondent evaluation of effectiveness of undergraduate management studies

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

Table 4 - Improvements to management studies suggested by respondents

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