Int. J. Engng Ed. Vol. 18, No. 3, pp. 321–330, 2002
Printed in Great Britain.

0949-149X/91 $3.00+0.00

An Evaluation of Undergraduate Engineering Management Studies*

STUART PALMER
School of Engineering and Technology, Deakin University, Geelong, 3217, Australia.
E-mail: spalm@deakin.edu.au

In 1996, a major review of engineering education in Australia recommended a move from a course accreditation regime based on prescribed inputs to demonstrated graduate attributes. In the move, the policy on management studies in engineering undergraduate courses has become less definitive and more open to interpretation. 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.

INTRODUCTION

AUSTRALIA HAS long recognised the importance of the inclusion of management studies in undergraduate engineering courses. In 1991, the Institution of Engineers, Australia (IEAust), mandated a requirement for 10% of Australian course content to be management studies. Since that time there have been a number of significant developments in engineering management education in Australia that have influenced undergraduate management studies. This paper summarises those developments and their impacts on management education in engineering undergraduate courses, and reports on research undertaken to evaluate the effectiveness of management studies in undergraduate engineering programmes at Deakin University, Australia.

UNDERGRADUATE ENGINEERING MANAGEMENT STUDIES IN AUSTRALIA

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' [1]. A 1972 survey of 1,426 practising Australian engineers found that 92% of respondents indicated that management studies should be included at the undergraduate level [2], 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 [3]. The 1988 Australian government Discipline Review of engineering education (Williams Review) 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 [4].

The Australian engineering professional body that controls the accreditation of university undergraduate engineering programmes is the Institution of Engineers, Australia (IEAust). 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':

> 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. [5]

The policy was incorporated in the IEAust's Guidelines for Management Studies in Engineering Undergraduate Courses [5], which provided a rationale for management studies in undergraduate engineering courses, suggested a model study structure comprising 17 units of management studies, as shown in Table 1, and suggested a syllabus for each of the units.

Though quite detailed, the guidelines 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. It should be noted that this policy was not greeted with unanimous support by

* Accepted 4 August 2001.

Table 1. IEAust suggested model study structure for engineering management

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

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 [6].

In 1994 the Department of Employment, Education and Training (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 of a 10% management component in courses [7]. 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 into graduates an understanding of the context in which engineering functions, including 'economics, finance, accounting, teamwork and competition' [8]. 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 focusing 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. [9]

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? [10]

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 *about* 10% of total program content. [11]

Australia's '10% rule' has been held in high regard internationally as a benchmark for management studies in engineering undergraduate courses. On the face of it, the recent accreditation changes 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. From now on, the scope of such studies will be much more open to interpretation by individual institutions than has been the case since the 1991 10% rule.

ENGINEERING PROGRAMMES AT DEAKIN UNIVERSITY

The Deakin School of Engineering and Technology opened in 1993 and offers a three-year Bachelor of Technology (BTech), and four-year Bachelor of Engineering (BE), Masters and Doctoral engineering programmes in flexible delivery mode. The undergraduate programmes are delivered on-campus, full-time for conventional entry students. Mature students may study the programmes off-campus and/or part-time. In each year of the undergraduate programmes, one unit out of eight (12.5%) is devoted to 'engineering management' content. Table 2 provides a broad outline of the current syllabus of each unit (note

Table 2. Outline of current undergraduate management syllabus

Year level and unit	Syllabus outline
Year 1 Fundamentals of Technology Management	• Communication skills • Technology perspectives • Introduction to management concepts • Quality management concepts
Year 2 Managing Industrial Organisations	• Systems concepts for engineers and technologists • Managing people in organisations • Manufacturing and environment • Occupational health and safety
Year 3 Methods of Managerial Decision-Making	• Project management • Accounting and financial management • Operations research
Year 4 Strategic Issues in Engineering	• Technological forecasting and assessment • Policy design in engineering organisations • Issues in productivity improvement

that the fourth-level unit is not taken by students studying the three-year BTech course).

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 university student information database, graduates from the years 1996 (first graduates of the 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 have been important in practice; and
- evaluating the effectiveness of the management stream in the Deakin undergraduate engineering programme.

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 engineering students [12] and Australian engineering management academics [13], a 45-item management skills inventory was developed, as presented in Table 3, and respondents were asked to indicate which of these management skills had been important to them in their professional practice since graduation.

RESULTS

Response rate

From a total of 135 graduates from the period 1996 to 1999, 20 surveys were returned as not deliverable. From the remaining 115 potential respondents, 42 completed questionnaires were received, a voluntary response rate of 36.5%.

Demographic information

The age range of respondents varied widely (23–54 years), with a mean of 30.2 years and

Table 3. 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 management	Theories of management
Teamwork	Lifelong learning	Systems approach
Time management	Public relations	Maintenance management
International business	Strategic management	Cost estimation
Risk management	Environmental management	Industrial relations
Design management	Supply management	Change management
Dealing with customers	Decision-making	Negotiation
Report writing	Contract management	Forecasting
Motivation	Competition	Conflict resolution
Occupational health & safety	Creativity	Information management
Logistics	Inventory management	Work/time study

standard deviation of 7.4. The proportion of female respondents was 19.0%; the proportion of male respondents was 81.0%. The proportion of on-campus students was 71.4%; the proportion of off-campus students was 28.6%. The breakup of the engineering disciplines studied by the respondents was: Manufacturing = 57.1%, Environmental = 26.2% and Mechatronics = 16.7%.

Experience in engineering practice

The years of work experience reported by the respondents varied from 0 to 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.

Experience in management roles

The range of specific management roles reported as held by respondents is given in Table 4.

Management skills that have been important in practice

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

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*.

Effectiveness of the management stream in the deakin undergraduate engineering programme

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 5 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).

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 6 shows the responses received.

DISCUSSION

Response rate

The fact that 14.8% 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.

Demographic information

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 ($\chi_1^2 = 0.298$, $p > 0.58$). The graduating discipline proportions of the target group were Manufacturing = 54.8%, Environmental = 20.7% and Mechatronics = 24.4%; these were not significantly different from the respondent group ($\chi_2^2 = 0.949$, $p > 0.62$). This suggests that the actual respondent population is a representative sample of the target potential respondent group.

Two significant demographic correlations were found to relate to study mode. The mean age of off-campus students ($M = 37.8$ years, $SD = 6.5$) was significantly higher than on-campus students ($M = 27.4$ years, $SD = 5.6$) ($t_{18} = -4.834$, $p < 0.0002$). Off-campus students were more likely to be undertaking a three year BTech course (56.3% of BTech enrolment), whereas on-campus students were more likely to be undertaking a four-year BE course (87.5% of BE enrolment) ($\chi_1^2 = 8.75$, $p < 0.0031$). These results concur with prior research in the Deakin School of Engineering and Technology [14] that indicates that off-campus students are principally mature, typically study part-time because of full-time work commitments, and choose the BTech as an attainable goal to upgrade their prior trade or technical qualifications into the professional workforce. The corollary is that on-campus students predominately enter engineering studies directly from high school, and normally aspire to the four-year BE professional engineer status.

Table 4. Management roles reported as held by respondents

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

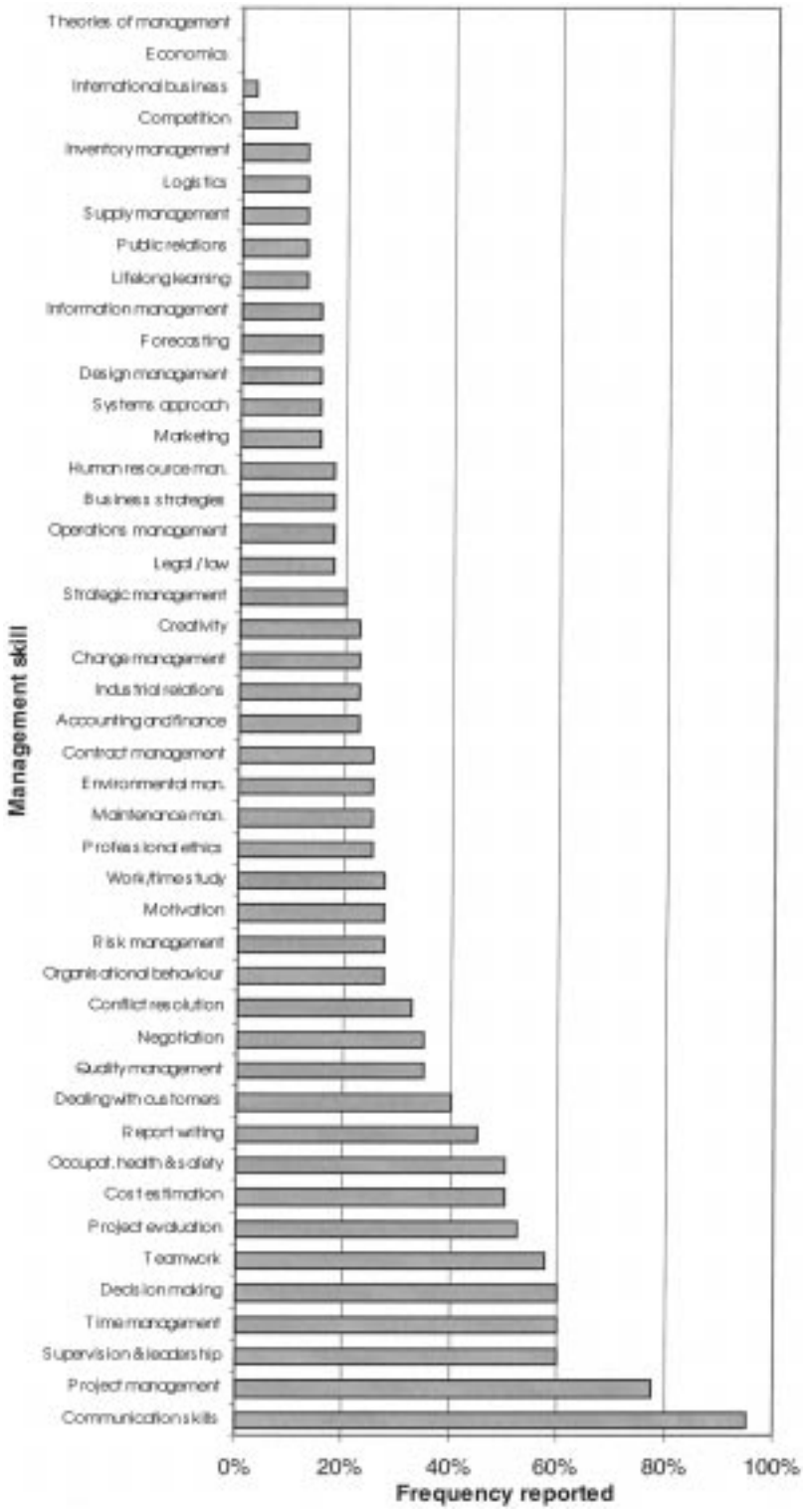

Fig. 1. Importance of management skills as identified by respondents

Experience in engineering practice and management roles

The experience in these areas reported by the respondents confirms that management responsibilities are part of the practice experience of recent engineering graduates in a wide range of industries and sectors.

Management skills that have been important in practice

The most frequently reported management skills (reported as important by 45% of respondents or more) include *communication skills*, *project management*, *supervision and leadership*, *time management*, *decision-making*, *teamwork*, *project*

Table 5. Respondent evaluation of effectiveness of undergraduate management studies

Statement regarding management studies	Mean rating	Standard deviation
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	3.5	1.1
If you entered engineering as a mature student, your management studies helped formalise your understanding of management gained from your prior work experience	3.9	1.2
If you studied principally on-campus as an undergraduate, your classroom activities and assessment tasks helped develop your understanding of engineering management	3.4	1.0
If you studied principally off-campus as an undergraduate, your course materials and assessment tasks helped develop your understanding of engineering management	3.8	1.1

evaluation, *cost estimation*, *occupational health and safety* and *report writing*. These first 10 skills are all important generic professional practice skills that are 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 than 45% 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 were reported by a smaller proportion of respondents. Other activities in the middle band may relate to higher-level management issues that many recent graduates are yet to experience, such as *contract management*, *change management*, *strategic management*, *business strategies* and *systems approach*, and therefore again have a lower rate of reporting.

Table 6. 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 crash courses
Team playing and open communication
More real world situations, rather than textbook situations
Body language

Effectiveness of the management stream in the deakin undergraduate engineering programme

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 ($f_{3,36} = 3.79$, $p < 0.019$). Older students are likely to have had more experience of the engineering workforce, and hence have 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 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.

Other findings

Two moderately significant differences in the reporting rate of a management skill being important were noted between the qualifications gained by respondents. In Australia, the occupational classification 'engineering technologist' refers to a three-year BTech degree qualification that fills the occupational niche in the engineering workforce between professional engineer and engineering

Table 7. Correlations between management skills indicated as important by respondents

Respondents who indicated that this management skill was important . . .	. . . were more likely to indicate that this/these management skill(s) were also important	Significance
Quality management	Dealing with customers	$\chi_1^2 = 8.86$, $p < 0.0030$
	Competition	$\chi_1^2 = 8.25$, $p < .0041$
Professional ethics	Time management	$\chi_1^2 = 8.89$, $p < 0.0029$
Business strategies	Forecasting	$\chi_1^2 = 11.8$, $p < 0.0006$
	Creativity	$\chi_1^2 = 11.6$, $p < 0.0007$
Project evaluation	Cost estimation	$\chi_1^2 = 12.1$, $p < 0.0005$
Lifelong learning	Creativity	$\chi_1^2 = 10.8$, $p < 0.0010$
Time management	Work/time study	$\chi_1^2 = 10.1$, $p < 0.0015$
Public relations	Negotiation	$\chi_1^2 = 10.6$, $p < 0.0012$
Strategic management	Information management	$\chi_1^2 = 9.61$, $p < 0.0020$
Cost estimation	Contract management	$\chi_1^2 = 8.53$, $p < 0.0035$
Risk management	Report writing	$\chi_1^2 = 8.31$, $p < 0.0040$
Design management	Negotiation	$\chi_1^2 = 13.1$, $p < 0.0003$
Negotiation	Report writing	$\chi_1^2 = 9.81$, $p < 0.0018$
	Creativity	$\chi_1^2 = 9.34$, $p < 0.0023$
Forecasting	Inventory management	$\chi_1^2 = 9.08$, $p < 0.0026$
Motivation	Work/time study	$\chi_1^2 = 9.94$, $p < 0.0017$

associate [15]. Professional engineer and engineering technologist are classified as professional occupations; engineering associate refers to graduates of two-year study programmes in the vocational education sector. BTech graduates were significantly more likely (37.5%) to report that *operations management* had been important to them when compared to BE graduates (4.2%) ($\chi_1^2 = 7.388$, $p < 0.007$). BE graduates were somewhat more likely (66.7%) to report that *project evaluation* had been important to them than compared to BTech graduates (31.3%) ($\chi_1^2 = 4.829$, $p < 0.028$). These results perhaps reflect that a significant proportion of BTech students come from occupational groups focused on operations (engineering trades and engineering associates), and, as engineering technologist graduates, they are likely to continue in an operations role (in Australia it would be common to find engineering technologists working under the direction of a professional engineer). Conversely, it is perhaps more likely that professional engineering graduates would find themselves involved in project planning and evaluating project feasibility sooner than their engineering technologist counterparts.

A number of significant positive correlations were observed between the management skills indicated as important by respondents. Table 7 provides a summary of these correlations and an indication of their significance. No strong negative correlations between management skills indicated as important by respondents were observed.

Table 7. Correlations between management skills indicated as important by respondents

The association of *quality management* and *dealing with customers* is not surprising. The modern concept of 'quality' places the customer/end-user in a position of central importance in determining and delivering quality [16]. Likewise, the association of *quality management* and *competition* acknowledges that quality is a strategic issue in the modern business environment [17].

Two central elements of the concept of the 'professional' and 'professionalism' are adherence to a code of ethics or rules of conduct, and a claim to independence or autonomy in practice. The practising technology professional often enjoys a high degree of autonomy, even as an employee engineer. The association of *professional ethics* and *time management* may represent the exposure of the recent engineering graduate to professional freedom in their work, and their realisation that the effective and productive use of their time can depend significantly on their self-motivation and personal commitment to employing their time efficiently for the achievement of organisational goals.

There is no surprise in finding a strong association between *business strategies* and *forecasting*. The strategic planning process, indeed all planning processes, involves the forecasting of future environmental conditions. Likewise, a strong association between *business strategies* and *creativity* is not unexpected. The Nobel laureate in economics Robert Solow argues that technological progress is the major factor that contributes to economic progress [18]. Technological progress and innovation are the result of research and development, which in turn is dependent on invention and creativity.

Project evaluation and *cost estimation* are natural partners. Whether evaluating a project proposal, performing a project progress review or conducting a post-project audit, accurate cost estimation is important.

Organisational change is now viewed as an ongoing process rather than an event, and can be viewed from many perspectives, including that of the individual(s) who facilitates organisational transformation through initiative and creativity [19]. Organisational change means that students

now entering the workforce may experience 8 to 10 different jobs, and, apart from skills in an academic discipline, a key requirement for personal success will be lifelong learning skills and attitudes [20]. Whether *creativity* is the source of change or the skill to adapt to change, *lifelong learning* will be a key strategy for the renewal of skills and knowledge required to stay competitive and innovative.

Finding a link between *time management* and *work/time study* can be explained by an interest in time and its effective use as a personal and organisational resource.

Both *public relations* and *negotiation* are related under the umbrella of the marketing function, and are additionally closely aligned to the concept of communication and its management. The systematic linkage of these two skills/areas is illustrated by the damage that can be caused to a corporate negotiating position by poorly conceived public communications [21].

The emerging view of organisational knowledge and information technology as strategic enablers for business performance supports the observed association between *strategic management* and *information management*. The strategic value of corporate information and knowledge comes not merely from putting information in databases, but from leveraging this information into the organisation's operations – from active information management [22].

As with *project evaluation*, *cost estimation* is a natural partner of *contract management*.

The observed link between the reporting of *risk management* and *report writing* may arise from the central role that documentation plays in risk management systems. The process of risk management includes risk identification, risk assessment, risk response and risk documentation [23]. Processes for risk management must be documented, as must occurrences of reportable incidents identified under the risk management system.

Statistically significant co-reporting of *design management* and *negotiation* may result from the human resource management issues that arise in the management of design professionals. Design professionals, such as engineers, value autonomy and recognition of their technical expertise. The 'situational leadership' approach suggests that improved motivation can be derived from carefully controlling the assignment of work. Less skilled staff may require close direction, whereas experienced staff may work better in situations where they are given the required goals but are also given significant freedom regarding the means by which these goals are achieved [24]. Dealing with experienced professionals in this manner may require negotiation regarding delivery dates, acceptance criteria, etc. Additionally, those with design management responsibility may find themselves negotiating those characteristics of their projects for which agreement would normally have to be reached, including scope of work, budget and time-frame.

Respondents indicated an association between *negotiation* and *report writing*, and *negotiation* and *creativity*. The literature strongly suggests that creativity is the key to successful negotiation that goes beyond win–lose, compromise, avoidance or accommodating strategies, and seeks a 'win–win' goal [25]. Likewise, a key factor in ensuring that the outcomes from successful negotiation are fully realised is clear documentation and reporting, once a full understanding has been reached by the negotiating parties [26].

A link in the reporting of *forecasting* and *inventory management* is supported by the modern goal of supply chain management, which looks beyond simple control of stock levels to the full integration of logistics as a loop from customer service levels to forecasting [27].

An association between *motivation* and *work/time study* was observed. Though often viewed as somewhat 'Taylorian', work measurement and time study still play an important role in the quantification of time and cost, and in providing goals and incentives for some employees [28].

CONCLUSION

Other 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. [29]

> Engineering Faculties should: . . .emphasize design, problem solving, the impact of engineering on society and the environment, communication, teamwork, leadership and practical experience . . . [30]

> 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.). [31]

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 [32]. In Australia, the largest MBA programme is one designed principally for engineers and focused

on the management of technology [33]. Recent developments in engineering management education in Australian undergraduate courses would appear to be moving in a direction counter to developments of the previous three decades, and towards a reduced importance for engineering management studies.

A 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 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 [34]. 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 practising professionals.

REFERENCES

1. B. E. Lloyd, *The Education of Professional Engineers in Australia*, Melbourne: The Association of Professional Engineers, Australia, (1968) p. 43.
2. PE Consulting Group (Australia) Pty. Ltd., *The Role of the Professional Engineer*, Melbourne: Australian Commission on Advanced Education, (1972).
3. B. E. Lloyd, E. Stokes, M. R. Rice and W. N. Roebuck, *Engineering Manpower in Australia*, Melbourne: The Association of Professional Engineers, Australia, (1979) p. 220.
4. B. C. Williams, *Review of the Discipline of Engineering*, Canberra, Australia: Commonwealth Tertiary Education Service, (1988).
5. Institution of Engineers Australia, *Guidelines for Management Studies in Engineering Undergraduate Courses*, Canberra, Australia: The Institution of Engineers, Australia, (1991).
6. B. E. Lloyd, *Australian Professional Engineering Courses: Percentage Distribution of Content by Category—Averages by Engineering School*, unpublished, (1999).
7. G. Caldwell, *Report on the Impact of the Discipline Review of Engineering*, Canberra, Australia: Department of Employment, Education and Training, (1994).
8. P. C. Johnson, *Changing the Culture: Engineering Education into the Future*, Barton, Australian Capital Territory: Institution of Engineers, Australia, (1996).
9. Institution of Engineers Australia, *Manual for the Accreditation of Professional Engineering Courses*, Canberra, Australia: The Institution of Engineers, Australia, (1997) p. 4.
10. E. J. Young, Management education must be clarified (letter to the editor). *Engineers Australia*, **70**(10), (1998) p. 13.
11. Institution of Engineers Australia, *Manual for the Accreditation of Professional Engineering Programs*, Canberra, Australia: The Institution of Engineers, Australia, (1999) p. 6.
12. S. Palmer, Engineering management studies as part of continuing engineering education, *International Journal of Continuing Engineering Education and Lifelong Learning*, **9**(2), (1999) pp. 128–137.
13. S. Palmer, Management education in Australian engineering undergraduate courses, *The Engineering Management Journal*, **12**(3), (2000) pp. 3–10.
14. H. Briggs, Towards student-centred engineering education at Deakin University. *Proc. 12th Biennial Forum of the Open and Distance Learning Association of Australia*, Vanuatu, (1995) pp. 2–11.
15. Institution of Engineers Australia, *National Generic Competency Standards for Stage 2: Professional Engineers, Engineering Technologists, Engineering Associates*, Barton, Australian Capital Territory: The Institution of Engineers, Australia, (1999).
16. W. E. Deming, *Out of the Crisis*, Cambridge, MA: MIT Center for Advanced Educational Services, (1986) p. 5.
17. J. M. Juran and A. B. Godfrey (eds.), *Juran's Quality Handbook*, New York: McGraw-Hill, (1999) p. 2.16.
18. T. Khalil, *Management of Technology*, Bangkok: McGraw-Hill, (2000) p. 23.
19. B. H. Kemelgor, S. D. Johnson and S. Srinivasan, Forces driving organizational change, *Journal of Education for Business*, **75**(3), (2000) pp. 133–137.
20. B. B. Sumberg, Linking business needs and lessons learned to education, *Training & Development*, **54**(2), (2000) pp. 70–71.
21. D. Ertel, Turning negotiation into a corporate capability, *Harvard Business Review*, **77**(3), (1999) pp. 55–64.
22. R. Cross and L. Baird, Technology is not enough: Improving performance by building organizational memory, *Sloan Management Review*, **41**(3), (2000) pp. 69–78.
23. A. Basu, Practical risk analysis in scheduling, *Transactions of American Association of Cost Engineers International*, **1998**(1), (1998) pp. 1–4.
24. W. S. Humphrey, *Managing Technical People*,. Addison Wesley Longman, (1997) p. 67.
25. A. E. Schwartz, Creative collaborations, *Executive Excellence*, **14**(8), (1997) p. 15.
26. A. Fowler, *Negotiation Skills and Strategies*, Exeter, UK: Short Run Press Ltd., (1990) p. 88.
27. F. B. Lawrence, Closing the logistics loop: A tutorial, *Production and Inventory Management Journal*, **40**(1), (1999) pp. 43–51.

28. S. A. Lawrence, The need for work measurement: Some observations on the current state of affairs in the business world, *Institute of Industrial Engineers Solutions*, **29**(12), (1997) pp. 16–19.
29. L. E. Grinter, *Report on Evaluation of Engineering Education*, Washington, DC: American Society for Engineering Education, (1955).
30. The Canadian Academy of Engineering, *Engineering Education in Canadian Universities*, Ottawa: The Canadian Academy of Engineering, (1993).
31. Working Group on Lifelong Learning and Continuing Education in Engineering, *Lifelong Learning in Engineering Education: A Call to Action*, Leuven: Higher Engineering Education for Europe, (1998).
32. S. Hegarty, Do MBAs lead to a better job and a bigger salary? *Works Management*, **49**(2), (1996) pp. 61–65.
33. D. Ashenden and S. Milligan, *The Australian: The Good Universities Guide—Postgraduate and Career Upgrade Courses in 2000*, Subiaco, Western Australia: Hobsons Australia, (1999) p. 25.
34. E. J. Young, Developing interest and motivation in engineering management for engineering students, *Proc. 9th Annual AAEE Convention and Conference*, Ballarat, Victoria, Australia, (1997) pp. 206–210.

Stuart Palmer graduated in electronics engineering and worked in private industry for eight years with a consulting engineering firm as a business unit manager. In that time he also completed a Master of Business Administration 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 undergraduate and postgraduate levels. Stuart Palmer 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.