

Using successful graduates to improve the quality of undergraduate engineering programmes

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This paper reports on a study of engineering graduates identified as high performers by their work supervisors. The study involved 20 graduates from different universities working in seven companies covering electrical, civil, mechanical, telecommunications and environmental engineering. The aim of the study was to identify the capabilities that were seen to be most important for successful engineering practice during the first few years after graduation, and to evaluate the extent to which universities were typically developing these capabilities. The reported study is a pilot for a larger scale study of a number of professional disciplines which will be used to shape the ongoing evolution of the undergraduate programmes in these disciplines at UTS. The results reaffirm the fact that while technical expertise is a necessary capability for successful practice it is certainly not sufficient. A range of ‘emotional intelligence’ capabilities appears to be judged by graduates and their supervisors alike as being very significant success factors. By focusing on the entire undergraduate experience rather than just what is taught, course designers can do much to provide learning opportunities to develop the capabilities identified.

1. Preamble

Extensive data are available from a wide range of national and institutional satisfaction surveys of students currently enrolled in or just graduated from Australia’s universities.¹ Such studies consistently suggest students perceive universities to be of higher quality when they provide learning content and experiences that are demonstrably relevant to subsequent professional practice. However, until graduates have come to grips with the realities of sustained full-time work, they are not really in a position to make specific recommendations about what sorts of university assessment, curriculum and support constitute the best preparation for the complexities of current professional practice. Yet it is hard to find studies that have followed up graduates during their first 3–5 years of professional work to investigate this issue.

Of course, universities do use a range of procedures already to ‘backward map’ (Elmore 1979) from professional experience in order to improve undergraduate learning programmes. Common practices include the use of Course or Faculty

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1. The Graduate Careers Council of Australia delivers its graduate destination survey and course experience questionnaire to more than 100 000 graduates each year, with a 70% response rate. Each Australian university runs its own internal surveys—these include surveys which tap students’ satisfaction with the overall university experience, subject and teaching feedback surveys, research student surveys and a wide range of focus group studies. For details of the UTS tracking systems, see www.qdu.uts.edu.au and click on tracking systems.

Advisory Committees, Professional Accreditation Committees and employer surveys. However, the professionals involved tend to be very experienced and in senior positions. Because of this, they may no longer be familiar with the realities of the first few years of professional work, know what is most relevant for new graduates or understand the full range of contexts in which they must operate.

The research reported herein addresses the need to tap the experience of successful, recent graduates in particular professions in a comprehensive and systematic way. 'Backward mapping' from the work experience of such people in order to improve the undergraduate curriculum and its assessment constitutes a unique and underutilized approach to practice-based learning in tertiary education, world-wide.

In 2001 the University of Technology, Sydney (UTS), initiated a research programme for the area with two detailed pilot studies, one with IT graduates and the other with engineering graduates. It is the outcomes of the engineering component of this broader research programme which are reported in this paper.

2. Aims and approach

The study sought to identify the capabilities which are seen to be most important for successful professional practice in engineering during the first few years after graduation and the extent to which the universities at which the participating graduates had studied focused on these capabilities. The intention was to use the findings of the survey to make improvements in content, delivery, support and assessment of the undergraduate programmes in engineering.

The research was undertaken by the UTS Quality Development Unit in partnership with the UTS Faculty of Engineering's Associate Dean (Teaching and Learning) and seven key Australian engineering enterprises with whom the Faculty has worked in recent years.² A two-phase approach was used.

In phase 1, one male and one female engineer who had graduated between 3 and 5 years earlier were identified as high performers by one of the partner companies. The criteria for high performance included: delivery of projects on time, to specification; high levels of client satisfaction with their work; and high levels of supervisor and colleague satisfaction with their work.

The selected graduates and their supervisors were interviewed individually in detail by the research team and the senior workplace partner. A semi-structured interview schedule based on the study's capability and teaching and learning frameworks was used (Scott *et al.* 2001). The data generated were summarized and scrutinized by the research team and the Faculty of Engineering's Industry Advisory Network. Using the relevant conceptual frameworks, key issues and themes were identified. The ability of the study's professional capability and educational quality frameworks to accommodate data were also checked.

In phase 2 an online survey instrument based on the results of phase 1 was used to scale up the study with 20 graduates and 10 supervisors. This two-stage approach is one which was first used with great success in the 1970s by Parlett and Dearden (1977) in their evaluative studies of higher education in the USA.

2. Alcatel Australia, Alstrom Power, Barclay Mowlem Construction Ltd, Connell Wagner, Kirby Engineering, Ove Arup and Sinclair Knight Merz.

An optimal response rate to the online survey by the selected graduates was achieved because they were personally informed that they had been identified as a high performing graduate and asked to complete the survey by their company's Chief Executive Officer or delegate. The data gathering instrument, sample size and response rate for both phases of the engineering component of the research programme are summarized in table 1. Table 2 gives a profile of the graduates who participated in both phases of the study.

Table 3 summarizes the items which were generated from the study's phase 1 interviews,³ checked against equivalent research and then used in the phase 2 online

Phase	Data gathering instrument	Sample size successful graduates	Response rate successful graduates (%)	Sample size supervisors	Response rate supervisors (%)
One	Semi-structured interview schedule	2	100	2	100
Two	Online interview schedule	20	90	10	40

Table 1. Sample details.

Company	Alcatel	Alstrom	Barclay Mowlem	Kirby	Connell Wagner (phase 1 only)	Ove Arup	Sinclair Knight Metz
(count)	(3)	(4)	(3)	(5)	(2)	(2)	(1)
Current work in engineering	Civil	Electrical	Environmental	IT	Management	Mechanical	Other
(count)	(4)	(4)	(2)	(2)	(3)	(2)	(3)
Time with company	< 1 year	1 year	2 years	3 years	4 years	5 years	6 years
(count)	(3)	(4)	(2)	(2)	(3)	(2)	(3)
University at which UG degree was taken	Griffith	Qld Tas	Usyd	Wollon-	NSW Gong	UTS QUT	Not given
(count)	(2)	(1) (1)	(1)	(1)	(4)	(7) (1)	(1)

Table 2. Profile of participating graduates.

3. All respondents during phase 1 were strongly supportive of the capability framework. As one successful engineering graduate observed: 'I really like the framework—it is easy to understand and it combines the hard and the soft nicely. It shows how you need emotional intelligence in the context of achieving hard-nosed solutions'.

 Professional capability

Emotional intelligence—personal

1. Being willing to face and learn from my errors and listen openly to feedback
2. Understanding my personal strengths and limitations
3. Being confident to take calculated risks and take on new projects
4. Being able to remain calm under pressure or when things go wrong
5. Having the ability to defer judgement and not to jump in too quickly to resolve a problem
6. A willingness to persevere when things are not working out as anticipated
7. Wanting to produce as good a job as possible
8. Being willing to take responsibility for projects, including how they turn out
9. Having an ability to make a hard decision
10. A willingness to pitch in and undertake menial tasks when needed
11. Having a sense of humour and being able to keep work in perspective

Emotional intelligence—interpersonal

12. The ability to empathize with and work productively with people from a wide range of backgrounds
13. A willingness to listen to different points of view before coming to a decision
14. Being able to develop and use networks of colleagues to help me solve key workplace problems
15. Understanding how the different groups that make up my organization operate and how much influence they have in different situations
16. Being able to work with senior staff without being intimidated
17. Being able to give constructive feedback to work colleagues and others without engaging in personal blame
18. Being able to motivate others to achieve great things
19. Being able to develop and contribute positively to team-based projects

Intellectual capability

20. Knowing that there is never a fixed set of steps for solving workplace problems or carrying out a project
21. Being able to identify from a mass of detail the core issue in any situation
22. The ability to use previous experience to figure out what is going on when a current situation takes an unexpected turn
23. Being able to diagnose what is really causing a problem and then to test this out in action
24. An ability to trace out and assess the consequences of alternative courses of action and, from this, pick the one most suitable
25. Being able to readjust a plan of action in the light of what happens as it is implemented
26. Being able to see how apparently unconnected activities are linked and make up an overall picture
27. Being able to set and justify priorities
28. An ability to recognize patterns in a complex situation

Profession-specific skills and knowledge

29. Having a high level of current technical expertise relevant to my work area
34. Understanding the role of risk management and litigation in current professional work
37. Understanding how organizations like my current one operate

Generic skills and knowledge

30. Being able to use IT effectively to communicate and perform key work functions
 31. Being able to manage my own ongoing professional learning and development
 32. An ability to chair and participate constructively in meetings
 33. Being able to make effective presentations to clients
 35. Knowing how to manage projects into successful implementation
 36. An ability to help others learn in the workplace
 38. Being able to organize my work and manage time effectively
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Professional capability (*continued*)*Educational quality*

39. Focus more directly on the capabilities identified above as being important in university courses and assessment
40. Use real-life workplace problems identified by successful graduates as a key resource for learning
41. Make work placements which test out the capabilities identified in this study a key focus in each course
42. Use successful graduates more consistently as a learning resource in university courses (e.g. as guest speakers)
43. Decrease the amount of formal classroom teaching of basic technical skills and use self-instructional guides and IT to develop these
44. Include learning experiences based on real-life case studies that specifically develop the interpersonal and personal skills needed in my particular profession
45. When relevant, use IT to make learning as convenient and interactive as possible
46. Ensure that all teaching staff model the key attributes identified as being important in this study
47. Ensure that teaching staff have current workplace experience
48. Make assessment more real-world and problem-based and less focused on memorizing factual material
49. Use performance on the capabilities identified as being most important in earlier parts of this survey as the focus for assessment and feedback on all learning tasks

Table 3. Online survey scales.

survey. These items have been sorted into five capability scales and one educational quality scale and relate directly to our research aims and frameworks.

Respondents were asked to rate each of these items, first on their importance to successful professional practice and, second, on the extent to which the university at which they studied had addressed them (performance). They were then invited to explain their ratings and suggest ways of improving undergraduate learning, assessment and support programmes for engineers.

3. Results

Figure 1 presents a scatter graph of the mean ratings on importance and performance allocated to each of the items in table 3 by the selected graduates who responded to the online survey:

This diagram shows the mean rating given by respondents on the importance of each item for their successful professional practice and the extent to which the university at which the respondent studied had addressed that item (performance). Items high on importance and high on performance represent areas of good practice (the top-right quarter of figure 1). Items high on importance but low on performance (the bottom-left quarter of figure 1) identify potential areas for enhancement or follow-up. Items in the left sectors raise issues of relevance.

These quantitative results have been complemented by a thematic analysis of the extensive qualitative data generated during the interviews in phase 1 and from student comments on their ratings in the online survey.

Specific discussion of these results is presented below in three parts. In the first part the capabilities rated as most important by respondents in phase 2, with an

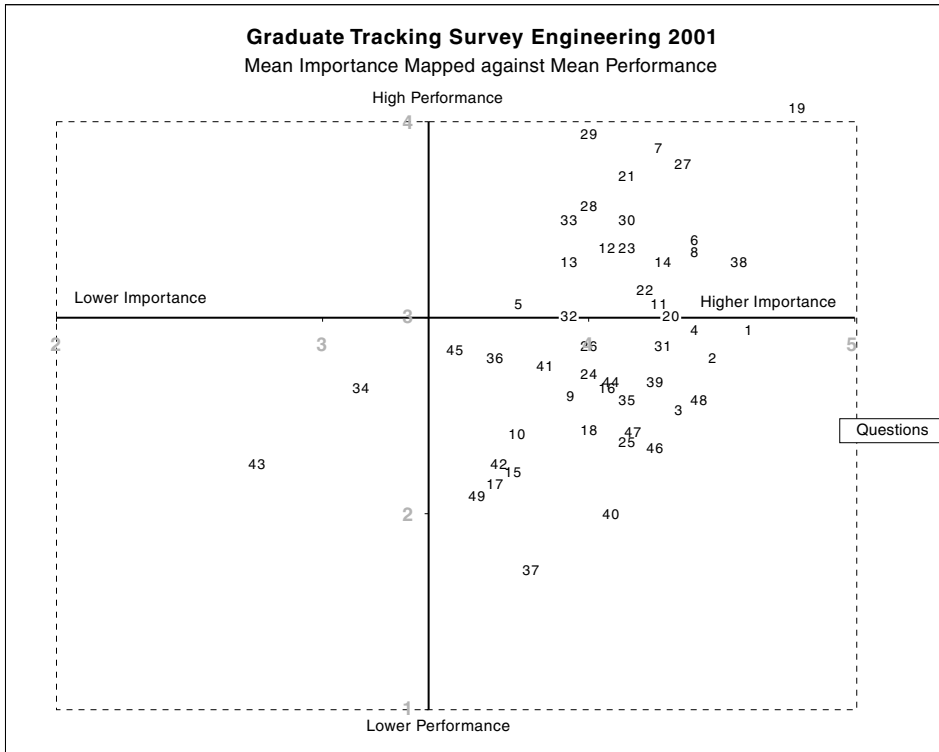


Figure 1. Graduate Tracking Survey 2001.

analysis of the comments justifying these ratings and the suggested ways of addressing them in university engineering programmes given by respondents in both phases. In the second part the extent to which respondents' universities were reported to have directly and effectively addressed such capabilities is discussed. Finally, strategies identified by respondents as most important in motivating them to learn in engineering programmes, how these relate to the suggested ways of addressing key capabilities and the implications for university learning, support and assessment priorities in engineering are noted.

It should be emphasized that results at this stage should be viewed primarily as indicative, due to the fact that this was a pilot programme. Only when a national study is undertaken can we be completely confident of their veracity.

4. Key capabilities and their implications for universities

Figure 1 indicates that the capability items ranked highest on importance for successful engineering practice during the early years of professional work come predominantly from the areas termed 'emotional intelligence' by Goleman (1998). The highest ranked item on importance concerns a social aspect of emotional intelligence: being able to contribute positively to the team-based projects (item 19). This is complemented by a group of items concerning personal aspects of emotional intelligence, namely: a willingness to face and learn from errors and listen openly to

feedback (item 1); having an understanding of one's strengths and limitations (2); being able to remain calm under pressure or when things go wrong (4); a willingness to persevere when things are not working out as anticipated (6); and being willing to take responsibility for projects, including how they turn out.⁴

There are two items ranked in the top 10 on importance which concern the engineer's intellectual abilities: being able to set and justify priorities (27); and knowing there is never a fixed set of steps for solving workplace problems or carrying out a project (20). This confirms findings from earlier research that successful practitioners in the professions need a 'contingent' not a 'linear' way of thinking.⁵ These intellectual abilities have some connection to the highly rated generic skill identified in item 38: being able to organize work and manage time effectively and, through this, knowing how to manage projects into successful implementation (item 35).

These findings align with our analysis of the detailed qualitative data generated in the phase 1 interviews and from respondents' comments in phase 2. These qualitative data consistently confirm two things. First, that it is when the unexpected occurs, when a project does not pan out as expected, when things are not running routinely, that professional capability in engineering is most tested. Second, that it is the *combined effect* of emotional intelligence, intellectual ability and key skills like those identified as most important in figure 1 that makes the difference at these times.

In this regard the following comments from respondents were typical:

When things are running routinely, only your skill base is tested. When things go wrong you must go back to more fundamental levels and scrutinize your approach.

When things are going wrong you are required to resolve the situation quickly and justify this to members of different parties. Consequently, your commercial, technical and interpersonal qualities are often tested at the same time.

Although it might, at first glance, appear that the key aspects of emotional intelligence identified above may not be teachable in a university engineering course, closer scrutiny of respondents' comments indicates that they are learnable and can be addressed in beneficial and more explicit ways in a university's assessment, learning, support and social systems.

4. The supervisors in the study produced similar ratings on importance to our graduate respondents. They too emphasized the importance of emotional intelligence, but gave more emphasis to the individual's ability to diagnose what is really causing a problem and to testing solutions in action (item 23). They also acknowledged that a high level of technical expertise is necessary but not sufficient for successful practice. They rated workplace understanding items like 36, 37 and 15 lower on importance. Their importance rating on item 20 (knowing that there is never a fixed set of steps for solving workplace problems), at 2.5, was almost half that of our graduates (4.3). Because of the relatively low response rate for supervisors it is hard to know if these differences are significant.

5. This attribute was first reported by Schön (1983) in his investigations of successful professionals in the early 1980s. It concerns the fact that successful professionals consistently 'read' a situation and what is causing a practice problem successfully and 'match' a uniquely appropriate solution to resolve it. Schön confirmed that no practice situation is ever identical to the ones which preceded it and is, therefore, unamenable to standardized methods of diagnosis or problem-solving. Effective practitioners use well-developed 'diagnostic maps' generated through reflection on earlier, similar, but never identical, situations to assist the process of figuring out what is going on and to identify solutions. That is, they know, as our respondents confirm, that there is never a fixed set of steps for solving workplace problems (item 20).

For example, the attributes that count can be given a central focus in the observation and assessment guides used by students during work placements; they can be given direct attention by workplace supervisors when reporting on the performance of students during industry practice; they can be identified in trigger films of engineers confronting real-world dilemmas; they can be addressed by academic staff when looking at how students react to negative feedback on assignments and university projects; and lecturers can explicitly seek to model these attributes and label what they are doing. Also, the data in figure 1 can be used during orientation programmes for new academic staff; preparation guides for student group-work can focus on how earlier teams have successfully put the capabilities into practice in their team projects, and so on. Simply starting off the undergraduate course by explicitly referring to the capability framework used in this study would, said respondents, give their learning far more relevance and focus. In this regard, asking new engineering students to complete the online survey given to successful graduates in this study and comparing the results can help identify capability gaps, areas for improvement and promote the importance of different attributes. More generally, it would provide a framework against which they could reflect on what is being learnt from their total university experience.

Comments like the following were typical:

The idea of emotional intelligence is really interesting. Just labelling it and showing how it works would be a great start in every university course. In my experience since leaving university it is critical.

Personal and professional development played a minor role in my university course. The focus was on the technical aspects of my profession and not on the personal attributes and qualities which I have found are so necessary to fulfil engineering roles in the workplace.

Being able to work in a team environment is of the utmost importance. People who are loners or who have difficulty discussing problems with others generally fail in this industry and are of no use to me . . . Problem-solving, initiative, perseverance as well as practicality are all important. EQ is as important as IQ (supervisor interviewed phase 1).

It was suggested that some of the attributes given priority by students might also be assessed at enrolment. This practice is seen in the sorts of affective tests now given to applicants seeking graduate entry into some medical programmes in Australia. An associated issue for careers' guidance officers to address is the tendency for many students to be attracted to the profession because they see their comparative strength as being in technology, rather than in interacting with people or dealing with ambiguity, an issue originally raised by Peruccis and Gerstl (1969).

Interestingly, the profession-specific content item 29 (having a high level of current technical expertise relevant to my work area) received a comparatively low rating on importance, even though respondents uniformly observed that it had received by far the greatest amount of teaching time in their course. This, they said, is not because such expertise is not vitally important to their practice but simply because it is necessary but not sufficient for successful performance. Respondents said it is one's ability to know when and when not to deploy this technical expertise and how continuously to update it that makes the difference, not simply being able, as one respondent put it, 'to correctly regurgitate specific skills and knowledge at exam time'. There was general agreement that the 'half-life' of the specific skills and

knowledge acquired during a university course is becoming increasingly shorter and that, because of this, strategies for using reciprocal networks of colleagues to help solve ongoing problems and, through this, to update expertise in the context of daily work was becoming increasingly important. They said that learning profession-specific content serves the important purpose of providing the 'scaffold' around which such subsequent workplace learning can be developed. This has direct implications for how we enable students to develop the generic skills necessary for career-long professional learning.

As our respondents observed:

Effective professional practice is about being able to negotiate your way through multiple perspectives.

It's no good having technical expertise if you can't use it properly. And to do this you need to be able to figure out what is going on, listen to people, see the situation from their perspective, build up a team, carry out a plan of action, use your networks and think laterally. It's the whole mix that counts not just the technical bit.

Respondents repeatedly emphasized that the most appropriate way to develop and assess this combination of attributes is through studying, analysing, experiencing and seeking to resolve real-world problems which have an emotional, intellectual as well as a technical dimension, problems drawn directly from the practical experience of graduates in their first few years of professional work. A curriculum in which groups of students sought to figure out how best to handle the technical, human, ethical and cognitive dimensions of such real-world case studies and had an opportunity to compare their diagnosis and plan of action with what the actual project team had done was seen to be a particularly beneficial way to integrate the various dimensions of capability identified.

Problems in university subjects generally have a singular result (i.e right or wrong). The workplace often has multiple solutions to problems, none of which are obviously the best. Personal judgement and opinion always come into play. The ability to judge each solution on its merits and to communicate this to others is very important in my role.

A number of respondents said that teaching the routine, set, technical components that are so important for their work could be given less emphasis in face-to-face classes and might be learnt more efficiently in other ways. In this regard there is considerable potential to use recently developed self-managed learning tools and resources, including interactive, online learning. However, as respondents' ratings and comments on item 43 indicate, they are either unaware of these developments or were unimpressed by the way they were used in their undergraduate course. If such strategies could be successfully used for routine skill-based learning, class time would be freed up for more integrated, problem-based approaches. This would be consistent with the highly successful problem-based approach first developed for medical education at McMaster University in Canada and later successfully implemented at the University of Newcastle in Australia (Feletti 1992).

5. University coverage of the capabilities identified as most important

As figure 1 indicates, some capability items with high importance ratings were reported also to have received high levels of focus by the university at which

respondents had studied. These include: being able to develop and contribute to team-based projects (item 19); being able to set and justify priorities (27); having a willingness to persevere when things are not working out as anticipated (6); and being able to develop and use networks of colleagues to help solve key workplace problems (14).

It must be emphasized that our graduates repeatedly pointed out in both phases of the study that it is the total university experience that can help develop such capabilities, not just what happens in the classroom. For example, the ability to network, use peer support and develop interpersonal skills can receive support from the whole range of formal and informal experiences encountered whilst at university.

It should be noted that the university course is a small part of the whole 'university experience'. Learning interpersonal skills in a course is usually not effective.

The intellectual abilities you list were not really covered in my university subjects. However, they were developed and used in order to study and pass my assignments and exams.

I think a lot of the ways in which university prepared me for these different requirements are not directly related to the course work, but depended on the interactions with others in my course and amongst my peers. Having such a network really helped in keeping things in perspective and providing support and advice.

This is why enhancing the social and support components of university provision in a way which encourages productive, collaborative relationships, sensitivity to other cultures and backgrounds and work on team-based activities is so important. First-year engineering orientation camps are one example of how the total experience at university can be more strategically used to address the key capabilities identified in this study.

Other items, like 7 (wanting to produce as good a job as possible), 3 (being able to identify from a mass of detail the core issue in any situation) and 29 (having a high level of technical expertise) were also rated high on university performance in addressing them, although their importance rating was lower.

Items of high importance which received low ratings on performance include ones which are predominantly from the emotional intelligence scales: being confident to take calculated risks and take on new projects (item 3); understanding one's personal strengths and limitations (item 2); being able to manage my own ongoing professional learning (item 31); being willing to face and learn from errors and listen openly to feedback (item 1); and being able to remain calm under pressure or when things go wrong (item 4). These high importance, low performance items identify potentially important areas for improvement in university provision—both educational and social.⁶ The fact that such attributes are learnable through both formal and informal university activities, even if they may not be teachable in the traditional sense, has already been raised. One respondent made the point in the following manner:

Most university courses try to teach communication skills in the context of formal presentations and subjects. A more useful approach is to look at giving us opportunities to communicate and work with others in many ways, like trying to relate technical information to a non-technical person and seeing what they understand or trying to communicate an idea to a workgroup and getting feedback on how well this worked.

6. The supervisors in the study rated a significant number of the same high importance items low on performance.

Some other items which received a comparatively high importance rating attracted very low performance ratings. These include: being able to readjust a plan of action in the light of what happens as it is implemented (item 25); and knowing how to manage projects into successful implementation (item 35). These confirm the importance of taking a project management, problem-based, case study approach to curriculum design and assessment, something which students emphasized when they addressed items on the educational quality scale (see later).

These findings align with the qualitative data from both phases of the study. Respondents consistently emphasized that many of these items were, as the discussion in the previous section noted, learnable and assessable in the university context even if they were not teachable in the traditional sense.

6. Optimizing the quality of undergraduate engineering education

In addition to being asked to identify ways in which key capabilities might most directly be developed in university engineering programmes, students also were asked to reflect directly on a set of items concerning the quality of their undergraduate programme in engineering, particularly in the light of their first few years of professional experience.

The educational quality item rated highest on importance concerned making assessment more real-world and problem-based and less focused on memorizing factual material (item 48). As one respondent suggested:

Allow more time for hands-on project work using real-world problems, allowing students time to evaluate different solutions and gain an understanding that there are different ways of doing things.

Other high importance items from the educational quality scale included: a need to focus more directly on the capabilities identified as being important in this study (39); ensuring that all teaching staff model these key attributes (46); ensuring that staff have current workplace experience (47); and using real-life workplace problems identified by successful graduates as a key learning resource (40).⁷

These preferred assessment and learning strategies align with those recommended when respondents discussed earlier how the engineering capabilities they have found to be most important might best be developed at university. Students consistently wanted to see an integration of theory and practice in their assessment tasks, in their learning activities and in their lecturers. We know that, from an analysis of 10 years' UTS qualitative data generated by Australia's course experience questionnaire, assessment, more than anything, drives where students put their emphasis in learning and that the form of assessment which is most valued is integrated and real-world relevant. These findings are also consistent with the recommendations which have emerged from a series of reviews of engineering education around the world over the last few decades (ASEE 1975, 1994, Meisen and Williams 1992, IEAust 1996) as well as from recently reported investigations (McMartin *et al.* 2000).

In terms of university performance in delivering these preferred learning and assessment strategies, figure 1 shows that none of these high importance items were

7. It should be noted that, with the exception of item 48, the importance ratings for the top items in the educational quality scale were generally lower than those received by the top items in the capability scales.

seen as being well handled by the universities at the time when respondents had studied with them. The performance ranking for all the educational quality items was consistently below three, with some, like item 40 (the use of real-life problems identified by graduates as a key learning resource), being as low as 2.00.

The issue then arises as to whether this is because the preferred strategies cannot be delivered by universities due, for example, to poor resourcing levels or, perhaps, because engineering academics prefer teaching technical material, rather than fostering interactive learning and reflective practice (Schön 1997). We do not believe this to be the case, as qualitative data from both phases of the study identified pockets of good practice where each of the key educational quality tests had been met within current resourcing parameters.

In terms of making assessment more integrated and less focused on memorizing factual material, there are many approaches that could be taken. One would be to use this study's capability framework to assist students to make sense of what is happening during work-placements and to assess directly their use of it in this task. Another would be to use case studies of real-world projects which included information on all aspects of the capability framework as an assessment task, and then ask students to outline and justify what they would do in such a situation. Later students could be asked to compare and contrast their approach with what the actual project team did. This sort of approach has already been used in some law and medical programmes. It would certainly seem desirable to decrease a tendency to overassess factual material in order to make room for assessment of students' ability to integrate this with other key aspects of capability. The study affirms the need to include the human and ethical dimension in at least some assessment tasks.

We are aware that acting on such findings will require a considerable shift in the thinking of academics and universities, away from a disaggregated, subject-based system towards a sharper, more integrated transdisciplinary approach to assessment, teaching and learning. However, if successful, such approaches will distinguish universities from training agencies and from the burgeoning number of online providers who assume that 'information is learning'.

The study's findings about making learning more practice-based and responsive are not new. However, by using the capability framework confirmed in this study more explicitly, we have an opportunity to give greater focus to this highly valued aspect of university study, right from the outset. For example, students can be alerted at orientation to the findings of studies like the present one, a successful graduate who participated in the study can explain why the various dimensions of capability identified are all important and the way in which the course addresses these in a developmental way can be explained. As noted already, the university's industry placement programme can focus on using and testing the framework; and case studies which illustrate how it operates can be scrutinized more consistently. Such strategies are used in many university courses and meet the relevance tests for high-quality university learning identified in this and other studies.

This study confirms the findings of earlier research identifying the critical importance of peer support and networking in effective career-long learning and project delivery.⁸ Therefore, directly labelling the importance of peer support and

8. In 1969 Tough found that being part of a well-developed, reciprocal peer network was the key resource in adult's learning projects. Since then his study has been replicated across the world with similar findings (Tough 1979).

networking, explaining how it can best be used and reflecting on its use throughout the engineering programme should be given more emphasis. Both formal and informal opportunities for it to be practiced should be more consistently provided.

As one respondent said:

Continue to encourage open co-operation between students for solving problems and meeting challenges together. This does not necessarily mean by using group-based assessments, as the initiative required to work together to solve individual problems is of paramount importance.

When giving feedback on learning, it is important to identify what aspects of the capability framework are being addressed well by students and, where there is room for improvement, how this might be achieved. Poor, unfocused feedback on learning continues to be a recurring concern for students in Australia's course experience questionnaire. Using a profession-specific graduate capability framework, like the one which has emerged from this study, to focus assessment design and feedback consistently is one way to address this concern. Making this use of the framework explicit at the outset of a course would also address another common complaint—a lack of clarity about what is expected of students in their course.

It is interesting that our respondents rated the use of IT and self-instructional learning guides lowest of all 49 items on both importance and performance (item 43). These findings need to be investigated further. It may be that, at the time when our respondents were at university, interactive web-based learning and the use of self-teaching materials were in their infancy and their rating simply reflects this. We know from other studies that students find self-managed learning guides and the use of IT for interactive learning especially helpful. However, we need to be sure of this, given the significant levels of investment currently being made in such areas and the need to find alternative ways of delivering important but routine technical information and skills. Cost-effective and productive use of IT to enhance university learning remains a major educational and equity challenge for higher education (Barraket *et al.* 2000).

In terms of university staff development, it is possible for academic staff undertaking a professional experience programme (PEP) in industry to give their workplace analysis focus by testing, using and refining table 3. This would help address the importance given by our respondents to having academic staff in engineering who have current workplace experience (item 47) and who model the attributes identified as being important in the study (item 46). The experience of these academics in using the capability framework to evaluate their PEP can be used back in the classroom to make learning relevant and to show how they link theory with practice.

There are interesting parallels between the above findings and earlier studies of higher education learning, both generally (e.g. Candy 1994) and specifically in the area of engineering (e.g. Steiner 1998).

7. Conclusion

This study of successful engineering graduates in their first few years of full-time work has established a comprehensive and profession-specific way of identifying exactly what should be emphasized in undergraduate curriculum, learning and assessment programmes in order to make university study relevant. It has demonstrated that the integrated capability framework used to guide this research can

comfortably accommodate all of the data generated in ways which make sense to the respondents. This argues in favour of its use by universities when seeking to formulate their graduate profiles for the various professions they serve.

The study has demonstrated that professional success requires far more than the possession of a high level of technical expertise, as important as this is. It demonstrates that it is the combination of emotional intelligence, a focused and contingent way of thinking, a specific set of generic skills as well as technical expertise that accounts for the successful delivery of engineering projects to specification and high levels of client and employer satisfaction.

Emotional intelligence—both social and personal—emerges as being a far more significant influence on successful early career performance than previously recognized; and there are indications from both our qualitative and quantitative data that, although such attributes may not necessarily be amenable to traditional, subject-based teaching, they are learnable. In this regard, it is very clear that we must look to the total university experience as a resource, not just to what happens in the traditional classroom.

The study confirms that the best starting point for the design of both assessment and learning in engineering is, therefore, a proven set of graduate attributes generated from the direct study of successful, early-career performers.⁹ A range of strategies for more directly developing the capabilities that count in first few years of professional practice have been identified and are discussed in detail in the Results section of the report.

Respondents' reflections on the quality of learning and assessment in their undergraduate course align not only with what they say best develops professional capability, but also with recent studies of what most motivates and sustains student engagement in productive learning at university. They confirm that there should be less assessment of routine skills and facts and more tracking of how well students can use their technical expertise in combination with their emotional and intellectual capabilities to diagnose and resolve effectively specific workplace problems and common dilemmas.¹⁰ How to address this finding poses universities, whose learning systems are based on separate, disaggregated subjects and credit point systems, with a considerable challenge. However, if this can be successfully done, it will reposition universities in a period of considerable competition as being about far more than the delivery of facts online or mere technical training.

In the next phase of the UTS research programme on the area, the two-phase methodology tested in the present study will be reapplied to other professional areas.¹¹ This will allow us to determine the extent to which some findings from the present study are common to many professions, whereas others may be more profession-specific.

9. The professional accreditation agencies for engineering courses in both Australia (IEAust) and the USA (ABET) have now adopted a graduate attribute framework for course accreditation.

10. In this context a dilemma is defined as 'requiring a choice (often under considerable time pressure) between two or more potentially appropriate courses of action. This generates a tension that must be resolved one way or the other' (Scott 1999).

11. The areas under consideration include business, design, architecture and building, teaching, journalism, communications, libraries, information technology, law, nursing, midwifery and health and various physical and biological sciences. A study of information technology is already underway and nearly complete.

It should be re-emphasized that, due to the comparatively small sample of respondents used in the present pilot study (20 successful engineering graduates from seven major Australian engineering firms), its findings should be viewed as indicative until we have been able to scale up the study. In this regard, the partnership between the university and the large employers in the pilot has considerable potential. So too does the fact that UTS is part of the Australian Technology Network of universities.¹²

If studies like the present one prove productive, then a range of change management projects must be commenced and effectively managed to action key findings. Doing this has already been identified as a key development in the UTS Strategic Plan 2001–04 and key lessons from 20 years' research on effective change management are being used to guide these developments. In this regard, the motto is 'good ideas with no ideas on how to implement them are wasted ideas'.¹³

This study builds on the University's already strong commitment to and reputation in the areas of practice-based learning, maintaining strong links to the professions and working in partnership with key employers and practitioners.

It is hoped that the approach successfully tested in this pilot study represents a key new strategy for making universities more relevant and engaging to people entering the professions. It is hoped that other tertiary institutions will follow our lead by seeking to listen more systematically and carefully to their graduates and to backward map from what they learn in order to enhance the quality of their students' total experience of university life.

This task, although challenging, is critical to Australia's future—tertiary education is the key investment in developing Australia's social, intellectual and creative potential. Without sensitive, critical, capable graduates who can successfully generate and implement relevant and imaginative solutions to the complex problems that Australia now faces, the country's social as well as economic future will be grim. The stakes are that high.

References

- ASEE, 1975, *Future Directions for Engineering Education—System Response to a Changing World* (Washington: American Society for Engineering Education).
- ASEE, 1994, *Engineering Education for a Changing World* (Washington: American Society for Engineering Education).
- BARRAKET, J., PAYNE, A. and SCOTT, G., 2000, *Equity and the Use of IT in Higher Education* (Canberra: Australian Government Publishing Service).
- CANDY, P., 1994, Developing lifelong learners through undergraduate education. Commissioned Report 28, Australian Government Publishing Service, Canberra.
- ELMORE, R. F., 1979, 'Backward mapping': implementation research and policy decisions. *Political Science Quarterly*, **94**, 601–616.
- FELETTI, G., 1992, Learning competence in medicine: the Newcastle approach. In G. SCOTT (ed.), *Defining, Developing and Assessing Higher Order Competencies in the Professions*. AVE Monograph Series (Sydney: UTS).

12. These universities are Curtin University of Technology, Perth, the University of South Australia, Adelaide, RMIT University, Melbourne, UTS, Sydney and Queensland University of Technology, Brisbane. Between them ATN universities cater for more than 137 000 students.

13. See Scott (1999) for a comprehensive outline of this research.

- GOLEMAN, D., 1998, *Working with Emotional Intelligence* (London: Bloomsbury).
- IEAUST, 1996, *Changing the Culture: Engineering Education into the Future* (Canberra: Institution of Engineers Australia).
- MCMARTIN, F., MCKENNA, A. and YOUSSEFI, K., 2000, Scenario assignments as assessment tools for undergraduate engineering education. *IEEE Transactions on Education*, **43**, 111–119.
- MEISEN, A. and WILLIAMS, K. F., 1992, *The Future of Engineering Education in Canada* (Ottawa: Canadian Council of Professional Engineers).
- PARLETT, M. and DEARDEN, G., 1977, *Introduction to Illuminative Evaluation. Studies in Higher Education Series* (California: Pacific Soundings Press).
- PERUCCIS, R. and GERSTL, J. E., 1969, *The Engineers and the Social System* (New York: Wiley).
- SCHÖN, D., 1983, *The Reflective Practitioner* (New York: Basic Books).
- SCHÖN, D., 1997, *Educating the Reflective Practitioner* (San Francisco: Jossey-Bass).
- SCOTT, G., 1999, *Change Matters: Making a Difference in Education and Training* (Sydney: Allen and Unwin).
- SCOTT, G., YATES, W. and WILSON, D., 2001, Tracking and profiling successful graduates, http://www.qdu.uts.edu.au/pdf%20documents/Success_Eng_Graduates.pdf
- STEINER, C., 1998, Educating for innovation and management: the engineering educators' dilemma. *IEEE Transactions on Education*, **41**, 1–7.
- TOUGH, A., 1979, *The Adult's Learning Projects: A Fresh Approach to Theory and Practice in Learning*, 2nd edn (Toronto: OISE Press).

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