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Professional development at university: student perceptions of professional engineering practice

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***Abstract:** This study examined student perceptions regarding professional engineering practice. We surveyed secondary school students attending engineering camps, engineering students in their first and fourth years, graduate engineers and experienced engineers to ascertain their impressions about what constitutes the daily activities of a professional engineer. We asked respondents to rate 39 aspects of engineering practice identified from the research later reported in (Trevelyan 2008). These aspects were rated by the participants according to their perception of the importance and the frequency encountered in engineering practice. We also asked where the participants learned or where they believed they were going to learn how to perform the various tasks associated with these aspects. We grouped the aspects into six functional themes; technical skills, technical knowledge, management, teamwork, communication, and interpersonal skills. We found that student perceptions of professional engineering practice changed significantly as they progressed from year ten, through first and onto fourth year engineering at university. Year ten students rated technical knowledge as highly important to engineering practice, with relatively low ratings given to the other five areas. It may be argued that this corresponds reasonably with general public perception of professional engineering activity. First year engineering students realised the importance of communication and management skills in engineering practice. They believed that the university would assist them in developing these skills to the expectations of industry. As students progress through their degrees however, as judged from the perception of final year engineering students, it becomes clear that university fails in training them for industry requirements. This is particularly evident with regard to management skills where we can observe the greatest deviation between industry and student responses of relative importance. The findings indicate that most of these tasks are learned on the job and the university does not contribute significantly in training graduates to perform to the level of industry expectations. It is likely that student perceptions regarding professional engineering practice are reflective of the emphasis that is placed on the various aspects of their technical and non-technical development in the educational curriculum. This raises concerns regarding the alignment of the engineering curriculum to industry requirements. It appears that despite adherence to the accreditation requirements for the engineering degree, graduates are not being produced with the required or desired attributes.*

Introduction

Unfortunately, there are few reliable reports on everyday engineering practice based on comprehensive and systematic study. In the few published reports on the subject, there is little consensus as to what do engineers really do or to what constitutes real engineering. In an attempt to improve our understanding of actual engineering practice and education, a systematic study has been carried out by the Engineering Learning and Practice Research (ELPR) research team at the University of Western Australia (UWA). The preliminary results provide strong evidence that coordinating the work of other people by gaining willing cooperation is a prominent aspect of engineering practice (Trevelyan 2007). Other aspects such as design appear to be much less prominent than expected.

As the part of this research, a longitudinal study of UWA engineering graduates is being conducted to see how graduates' careers develop and how graduates perceptions of their abilities change with time. According to the recent study investigating the time spent on different tasks by young graduates

revealed some surprising results. The most significant result is that around 60% of the time is spent interacting with other people, of which nearly two thirds is direct interaction and intervention (Trevelyan and Tilli 2008). On the basis of these studies, it is very clear that engineering education is faced with a major challenge to educate engineers to attain high level of technical knowledge and engineering expertise as well as to boost their coordination abilities to allow them to effectively interact with, negotiate with and coordinate other employees.

We conducted this study by taking a series of cross-section snapshot surveys. Ideally, one would undertake a longitudinal study by following a single cohort of students, surveying them at various intervals over their tertiary and workforce career, and wait for comparative results to emerge. However, while this is the long term plan, in the short term this strategy is not practical because of the considerable time required to yield comparative results (i.e. at least 4 to 6 years from undergraduate students and then additional time waiting for results from the cohort when they enter the workforce). To provide material for comparative analysis at this early stage of the study, four groups at various intervals in their study and careers were surveyed in late 2004 and early 2005. The four groups consisted of; secondary school students, first year engineering students, fourth year engineering students and practicing engineers of varying degrees of experience.

We had the opportunity to survey secondary school students as part of this project. The students were part of a three day 'Engineering Camp' held by the Faculty of Engineering at UWA for a limited number of year 10 (15 to 16 year-old) students who expressed an interest in studying engineering and applied to attend the camp. We saw this as an opportunity to gather the views of young people, not yet enrolled in the engineering degree, who were likely to undertake engineering studies at university. Effectively, we assumed their views about what they believe engineers do, to be similar to those of the general public.

Literature review and research questions

While some previous researchers have attempted to identify the desirable attributes and skills of engineering graduates based on the perceptions of students, academics and industry, most of this work has limited validity. Graduate competencies tested are often pre-determined from anecdotal evidence rather than derived from systematic field observations. In addition, these studies raise several concerns regarding sample size and the generalisability of the results.

Several reports demonstrate that communication is an essential component of most engineers' jobs. Recent graduates have been shown to spend around 64% of their time on some form of written or oral communication (Meier, Williams et al. 2000; Sageev and Romanowski 2001). These results illustrate the importance of providing engineering students with opportunities to develop good communication skills at university. Trevelyan (2007) reported that informal technical coordination and gaining willing cooperation was a dominant aspect of engineering practice among a wide range of engineers. Examples of coordination include: outlining design information for technical staff to produce drawings, discussing the status of the project with clients and subordinates, developing a network of contacts in relevant industries, supervising peers, subordinates and sub-contractors, etc.,.

Based on work experience of successful graduates the University of Technology, Sydney Quality Development Unit identified the most important professional capability as emotional intelligence both personnel and interpersonal (Scott and Yates 2002; Moulton and Lowe 2005). By focusing entirely on emotional aspects of graduate attributes, they neglected the numerous other aspects such as technical, business, finance, management, etc. In real-world problems these aspects are interconnected and it is only through meticulous planning and coordination efforts of all these aspects that engineering projects succeed. Nonetheless, there are many occasions in which an engineer has to persuade opposing team members or clients to accept a compromise. These tasks however, were not mentioned, even when discussing emotional social intelligence capabilities of graduates.

Similarly, (Martin, Maytham et al. 2005) applied qualitative interview analysis to explore the perception of recent University of Cape Town chemical engineering graduates. They found non-technical factors such as communication, team-work and interpersonal skills cannot be taught in isolation from the technical context in which they will be used. However these conclusions have been

drawn from a single perspective, only adopting the interview analysis approach, rather than a combination of strategies to decrease potential biases within the research (for example focus group, participant observation (Patton 1990)). Moreover, the authors did not study what actually occurs and how engineers solve real-world engineering problems. They focussed instead on graduate intentions and how they perceived themselves compared with graduates from other institutions.

In contrast to studying perception of recent graduates based on interviews, Nguyen (1998), Deans (1999) and Lang, Cruse et al. (1999), administered surveys based on existing information such as earlier literature, existing courses or the skills/competencies/attributes deemed desirable by national engineering bodies. For example, Deans (1999) asks graduates “to rate the emphasis which should be placed on the topics listed in Table 1 within the new course structure”. Nguyen (1998) says of her empirical research, “a survey questionnaire was developed to include seven generic skills and attributes, and several sub-groups (specialist skills) within each generic group, as proposed by Pudlowski and Darvall (1996), from which respondents could make a selection”. Lang (1999, p44) asks engineers and engineering managers “to rank 172 skills, knowledge descriptors and experiences that were mapped into the ABET 2000 Criterion 3 eleven outcome categories”. These examples of conducting a survey are typical and are based on earlier understandings of what engineers do in their work and therefore should learn as students. Taken together, we can conclude that the empirical literature dealing with what industry requires from graduates and the quality issues associated with engineering education, almost without exception, do not seem to be based on comprehensive fieldwork studies of engineering practice.

Given the relative scarcity of reliable information on engineering practice, an understanding of student perceptions could give useful guidance to educators. For example, how accurate are student perceptions of engineering practice? Do they change with time and progression through their courses? How variable are these perceptions? At a further level of detail, although we were unable to explore this question in our own study, it would be worth exploring the effect of close relatives working as engineers: do these students have a more accurate perception of engineering practice than others?

Methodology

The survey instrument used for the present study was developed from empirical research on engineering practice (Trevelyan, 2008). Interviews combined with field studies and focus groups have made a significant contribution to the understanding of engineering practice. The participants for this research were recruited from a range of engineering disciplines, industries, ages and years of professional experience.

From an initial set of 25 interviews and careful reviews of the limited published research on engineering practice, we determined aspects of engineering practice undertaken by engineers in their work. For example, one aspect is optimising existing designs to lower costs or increase productivity. Not all engineers that we have observed or interviewed engage in all aspects, however, each aspect has been substantiated by evidence from one or more engineers for whom it is a part of their work. Some aspects are common to all, where as others are more specialised. In the original study, the aspects were referred to as tasks. However, more recently we have referred to them as aspects because they are non-exclusive. For example, coordinating other people’s work may be part of a design task. We have so far been unable to define a mutually exclusive framework of tasks that can satisfactorily explain engineering practice.

We structured the survey to give us a multifaceted view of what our participants thought engineers did in the workforce. That is, participants were given a list of aspects of engineering practice, and were asked about the frequency which they believed these aspects were part of engineering practice, the importance of each aspect and where the skills required are acquired. For example, certain aspects may be perceived as very important but only be undertaken monthly, whereas other aspects may also be perceived as very important and undertaken daily.

In the questionnaire, 39 aspects were listed and participants were then asked to:

- rate the frequency at which each task was performed (never, yearly, monthly, fortnightly, weekly, daily, hourly) with a tick/cross in the appropriate box.

- rate the importance of each aspect (no importance, negligible importance, average importance, high importance, essential) with a tick/cross in the appropriate box.
- estimate where the skill required to complete that aspect was acquired (university, on-the-job, industry course, general life, other please specify).

At the time this study commenced we had identified more than 50 aspects of engineering practice. However, to prevent participants being daunted by an overly long survey, and so being reluctant to participate, we reduced the number of tasks to 39 by amalgamating some very similar tasks. The survey was administered to four groups: high school students (74 responses), first year UWA engineering students (192 responses) and fourth year UWA engineering students (135 responses) and practising engineers (49 responses) from industries spanning oil and gas, mechanical, civil and electrical engineering. The students were all given hardcopies of the survey to complete, while the practising engineers were sent electronic versions of the survey via email.

Results and discussions

Before beginning the analysis, we grouped the 39 tasks into six functional themes. We grouped aspects related to engineering science and problem solving as technical knowledge, aspects related to practical engineering skills as technical skills, aspects related to engineering project management as management, aspects related to working with different people, sharing information and work towards a common objective as teamwork, aspects related to building social relations and communicating the problem as communication, and finally aspects related to coordinating and interacting with people as interpersonal skills. Grouping responses into functional themes made it easier to perceive overall patterns in the perceptions of participant groups. Year 10 students only rated tasks that were categorised into the themes of technical knowledge and skills.



Figure 1: Frequency mean of functional themes of year 10, first year, fourth year and industry.

Figure 1 shows that communication is rated most frequently used, with the exception of the responses from year 10 students prior to the commencement of their engineering degrees. It appears that these students do not understand the level of communication that will be required of them. That requirement is apparently something students very quickly become aware of, because first and fourth year students understand the level of communication that is required. This perception is on par with the industry response in this category. The expected frequency of usage of technical knowledge and skills increases throughout the students' progression in their university degree, possibly due to the technical focus of the course content. Students think they are going to use technical knowledge much more often than practising engineers report. University actually seems to provide students with a misleading impression of professional engineering practice in this regard. Final year students tend to overestimate the required level of competency in both technical knowledge and technical skills. First year students, overall, have a more accurate understanding of engineering practice than the final year students in the present sample. This was an unexpected finding, resulting from this study.

Before they start their degree, year 10 students significantly over estimate the importance of technical knowledge relative to the response from industry (see Figure 2). In contrast, importance rating of technical skills of year 10 is far lower than the industry perception. First year and final year students rate the importance of technical knowledge highly but the trend is quite opposite with regard to technical skills. One of the reasons could be that engineering students don't get access to any hands-on learning until the later stages of their degree, and this is what enables them to experience technical skills and accurately rate its actual importance. One thing we do teach well at university is teamwork and our students are left with a slightly elevated sense of its importance. We can observe the trend in teamwork across the groups as the student's progress towards graduation the importance of teamwork becomes more essential. It is surprising that first year and final year students rate the importance of communication and interpersonal skills on par with industry, yet our biggest complaint from industry regarding graduate attribute deficits is that our graduates are poor communicators. The perception of importance of communication ability is the same in industry as with our first year and final year students. In light of the number of complaints received from industry, student ability to practice good communication however is clearly lagging the realisation of its importance. As students progress through their degree and start applying for jobs they realise the importance of interpersonal skills and this is clearly reflected in our results.

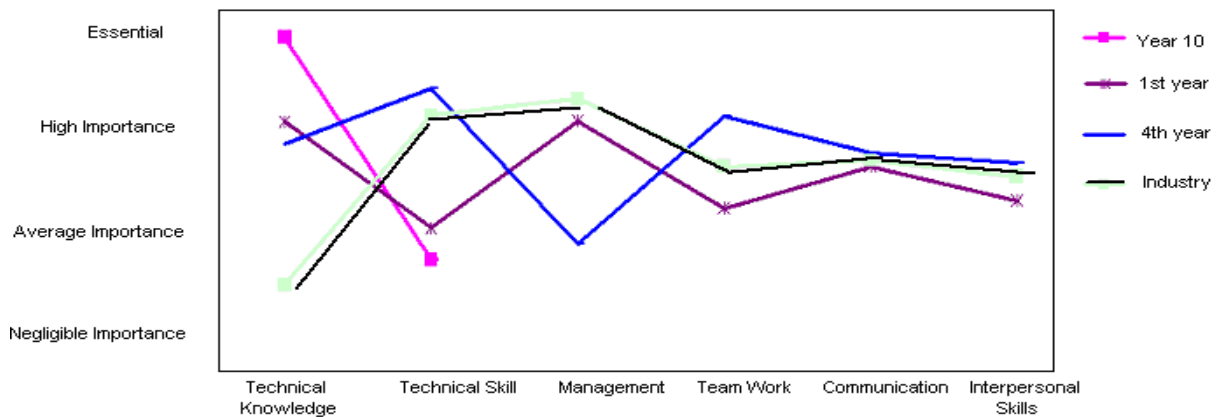


Figure 2: Importance mean of functional themes of year 10, first year, fourth year and industry.

As seen in Figure 3, the trend regarding the acquisition of skills is almost uniform from across all respondents. Industry perception is that none of the functional professional engineering practice themes are learned at university. This is a clear warning that should prompt serious re-evaluation of engineering education. Industry recognises that the necessary skills and knowledge for engineering practice are learned on the job. The ability to actively involve other people, and successfully influence the activities of group towards a common goal, included in the themes communication and interpersonal skills, are on the whole, not learnt at university. In addition, there appears to be no expectation by students that management, communication and interpersonal skills will be learned at university. Prior to starting their degree however, students do have some expectation, that most of the skills they will require as professional engineers, will be learnt at university We should expect that our graduates may therefore be disappointed with regard to their preparation for entry into the engineering profession.

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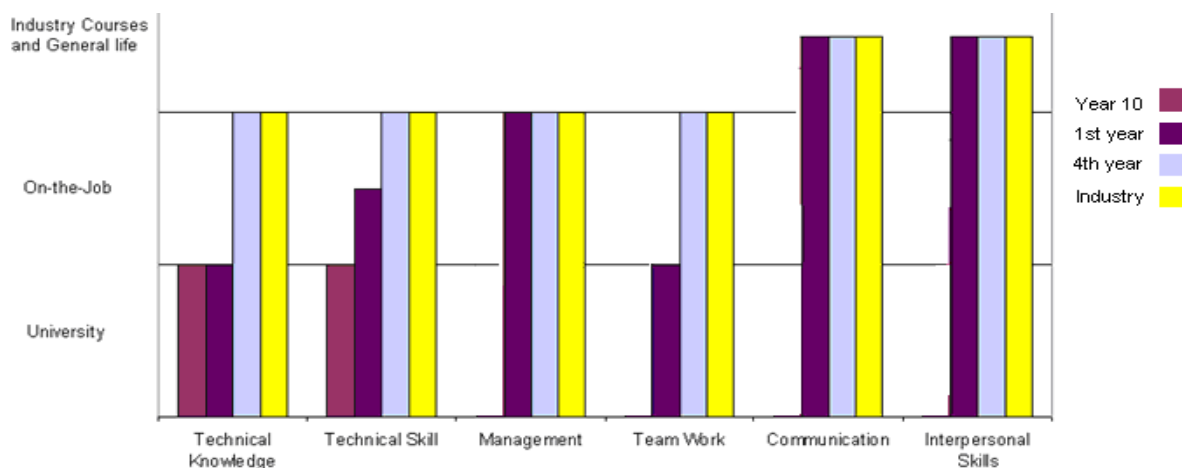


Figure 3: Acquisition mode of functional themes of year 10, first year, fourth year and industry.

Conclusions

The most interesting result from this study is that the perceptions of first year students, in terms of frequency and importance ratings of various aspects of engineering practice, align reasonably well with industry responses. First year students appear to realise the importance of communication and management in engineering practice and they do believe the university will play a prominent role in training them as professional engineers. As they progress however, from the perception of final year student, it becomes clear that university falls short in training them for industry requirements.

Given that so little information is available on engineering practice, results from this study raise challenging questions. Solutions to these questions will require much continued research.

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