World Transactions on Engineering and Technology Education
Vol.6, No.1, 2007

Enhancing the work readiness of engineering graduates

Kevin J. McDermott

University of South Australia
Adelaide, Australia

ABSTRACT: Australian universities continue in the Scottish tradition of vocational preparation. This is especially true for engineering undergraduate education. The pragmatic stance of potential and current students, the increased insistence by employers, emphases of professional institutions, and funding decisions by government are forces that compel university engineering departments to attempt to make their graduates more *work ready*. In this article, the author surveys methods that have been employed over many years, examines the consonance between their objectives and pedagogy, and comments on their perceived effectiveness. Recourse is made to the methods of systems engineering to provide a theoretical framework. Some of the results of a preliminary survey are given and tentative hypotheses are drawn. Because of the number of variables in delivery and uptake, it is probably not possible to rank the effectiveness of the various methods per se, but schools can know what to look for in gauging their value.

INTRODUCTION

It is a myth that universities are now or could ever have been disinterested centres for the discovery and dissemination of knowledge for its own sake. In both the east and west in medieval times, individualistic schools of thought were supplanted by institutions of higher learning that offered professional training in disciplines relevant to the needs of the dominant social apparatus. In the east, it was to staff a labyrinthine public service. In the west, it was for careers in the church or (in Italy) the world of commerce and international trade. Medicine probably found its way into the curriculum from Arab scholarship, but was always directed to practical ends. Science was at first a branch of philosophy, but with the emergence of the experimental method, became increasingly focused on matters of practical consequence. Modern universities offer professional training for a wide range of disciplines, and the research carried on within universities is intended to increase the relevance and efficacy of teaching for the professions [1][2].

Regardless of their form of organisation, there have always been expectations that universities should equip graduates for professional careers. Before reform, the link between the curriculum and career paths was often tenuous. Scottish universities were more focused than those in England and Australian universities have tended to follow the Scottish model from their inception. The Dawkins reforms of the late 1980s were intended to sharpen this focus: to make the *sandstone* universities more vocational, and that principally in disciplines deemed relevant to commerce and industry – in other words, to make them more like the existing institutes of technology/colleges of advanced education. The eventual outcome – the creation of 34 new *universities* and the elimination of the avowedly vocational institutions – was unplanned and no doubt unwelcome.

Nevertheless, other pressures are being brought to bear on universities, which make it increasingly important for them to be seen as sources of *work ready* graduates. The progressive introduction of *user pays* (albeit highly subsidised) education has conditioned students to expect that their degree will give them a competitive edge in gaining well-paid employment. Employers are now habituated to expecting assured quality from suppliers, and to shopping around to get the most finished and suitable product at the keenest price. When it comes to offers of employment, they expect that graduates will slot seamlessly into the organisation and be immediately productive. Professional institutions responsible for professional accreditation insist on graduates being well rounded and adept, as well as technically knowledgeable. Government agencies have instituted quality measures so that they can rank organisations and justify differential funding. Some of these metrics are simplistic, such as the uncritical use of the Graduate Destination Survey (GDS), but the net effect is to favour institutions with good employability of graduates. Academics also have a vested interest in producing work ready graduates, as the process of producing them establishes connections with comparatively well-resourced organisations and individuals, so leading to useful contacts for the future.

As we have seen, there is nothing new in attempting to better prepare graduates to enter the world of work, particularly in engineering where students are being groomed to translate their knowledge and skills to accomplish useful ends. It is more the case that as universities struggle to be competitive for their economic survival, they have to demonstrate that on some measure or other, their graduates are more work ready than are others.

In this article, the author looks critically at some of the ways that engineering schools attempt to do this and makes some suggestions for the future. An attempt is made to clarify critical

questions that need to be asked and answered. So far, only a pilot study has been conducted in order to refine the questions, so any conclusions based on the responses can only be regarded as tentative hypotheses.

SYSTEMS ENGINEERING MODEL

Systems engineering is a holistic approach to the management of large systems from conception to disposal. To use the methods of systems engineering to solve curriculum issues could be likened to using a sledgehammer to crack a nut. However, the author has encouraged the use of systems engineering approaches by final year project students and research Masters candidates with considerable success, and curriculum innovators could profit similarly.

Figure 1 shows a useful top-down conceptual model of the systems engineering process. The vertical levels of decomposition have been truncated to only show the most critical activities.

It will be immediately obvious from the diagram that the first action must be the precise formulation of customer requirements. The systems engineering model dictates that as each of these become known, the corresponding verification processes should also be planned so that it will be positively known when client expectations have been fulfilled. This rather begs the question – who are the customers or clients in a curriculum design for producing work ready graduates? The short answer to that is: anyone with an expectation of the system! As seen above, that comprises students, employers, professional institutions, government agencies and academics, as well as others.

Institutions will have differing means of interrogating clients to ascertain their requirements. Let us look at some of the characteristics of different client groups to highlight some of the considerations involved.

Students/Graduates

Students fall into two categories of sophistication: those without industrial experience and those with it. The latter are often part-time, in which case, although their insights are potentially the most valuable, they are underrepresented in student focus groups and fora. Other students with experience are those who have undergone meaningful industry placements. Their post-placement reports can be a useful source of information on their perceptions of gaps and consonances in their preparation for the placement and, therefore, for the world of work, *if* the report structure imposed requires them to reflect on these and report them.

Information from such instruments as the Graduate Satisfaction Survey (GSQ) is too abstract to be of much help in determining either what is necessary or what process is best for assisting students in their aim to be attractive candidates for the best jobs. Given that one of the problems with the GSQ is the low participation rate, exit interviews may be needed in the quest to extract student/graduate views.

Employers

Most Australian engineering schools would have advisory committees to assist in determining the content and process of programmes. There are issues with the composition of such groups and with their frequency of meeting. The employment sector is extremely diverse and therefore obtaining a sufficiently wide spectrum of opinion is difficult. It is desirable to have senior people on the committee because they have the clout within their organisations to make a difference, but their time is limited and sometimes their familiarity with day-to-day operations may also be limited.

Within the state of South Australia, the Electronic Industries Association (EIA) has launched an Electronics Industry Education Initiative $(ei)^2$, which aims to bring together the efforts and the resources of industry and the higher education institutions to increase the supply of work ready graduates. A pilot survey of randomly selected organisations from within the association yielded the following results – none statistically significant because of the small sample size:

- The majority of employers contacted believed that (electrical/electronic) engineering courses at universities contained much redundant material (such as unused mathematics, discrete device theory and esoteric technical material);
- The majority believed that too much time was devoted to developing non-technical skills;

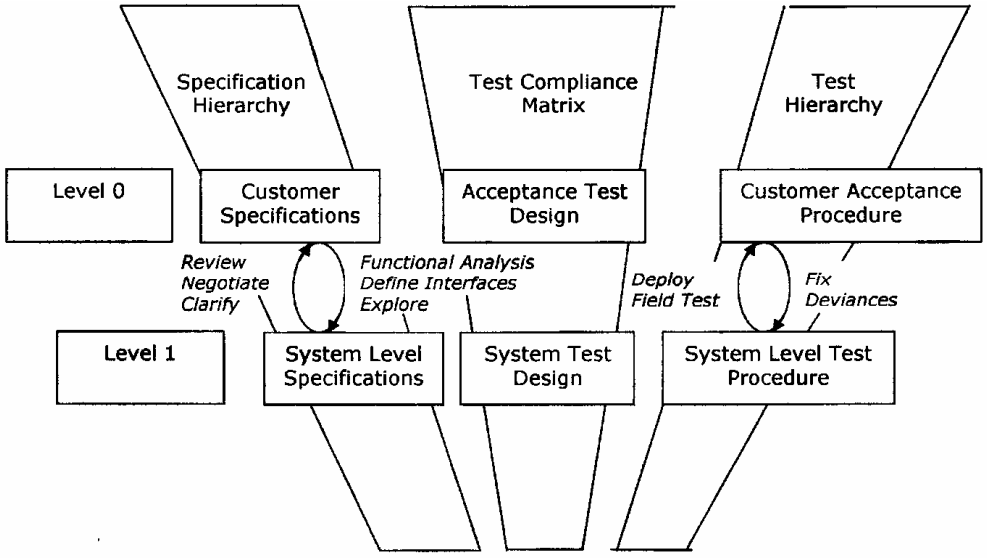

Figure 1: Vee-model of the systems engineering process (after [3]).

- The majority of the surveyed employers believed that the techniques used in their organisation were not adequately taught by universities;
- Proven technical ability demonstrated by course grades was the main selection criterion used when making appointments;
- There was an observable correlation between negative results and not having hired an engineer within the past five years;
- There was an observable correlation between negative results and not having sponsored a final year project;
- There was a weak correlation between negative results and not having had a student on placement during the past five years;
- There was an observable correlation between the negative view that too much time was devoted to learning non-technical skills and the response that the expected role of newly employed engineers was to maintain the organisation's skills base for existing practices. The other end of the role scale was that new engineers were expected to bring new insights and initiate new developments within the organisation.

One possible inference from the limited data is that there is a need to communicate better the objectives of contemporary engineering programmes to small employers, both to increase the attractiveness of employing new graduates and to promote the achievement of the aims of the work placement of undergraduates.

Professional Institutions

Internationally, professional engineering institutions play a vital role in monitoring the outcomes of and accrediting university programmes. When it comes to the formation of work ready graduates, professional institutions have vigorously promoted the need for graduates to have acquired generic skills to enable them to function in a complex commercial and societal environment (perhaps the employers opposing this view engage in non-complex operations amidst the generally more complicated global economy and society, but more likely it is because the implications are not thoroughly understood). Professional institutions do not prescribe how these skills are to be acquired, but accreditation panels do look for evidence of interaction with practitioners, eg the Institution of Engineers Australia (IEAust) requires evidence of exposure to professional engineering practice [4].

This is generally taken as adhering to the IEAust's policy on compulsory work experience, but need not be limited to that. Because the IEAust does not specify the expected *outcomes* of exposure to practice, there is a tendency for engineering schools to fail to specify objectives or to link assessment to objectives.

PRACTICUM

Perhaps harking back to a time when engineers learned the practice, as opposed to the theory of their craft through some form of tutelage, professional institutions make it a condition of accreditation that students must acquire at least minimum periods of practical experience prior to graduation. Generally, the experience per se is unmediated and the outcomes are therefore somewhat unpredictable, but this is rationalised as an inevitable consequence of authentic and undiluted contact with the employment sector. Most institutions will have some means to prepare students for the experience, a lesser number offer ongoing support, while an undetermined number will have some process to encourage reflection by students following their several experiences.

The frequency, duration, intensity and formality of such periods of experience vary widely between disciplines and institutions. Since engineering is a *doing* profession, and because it requires contributions over a wide spectrum of skill sets and levels of sophistication, it would be extremely rare for an engineering student to be relegated to the status of an observer. The employer will, therefore, have legitimate expectations of productivity and effectiveness, which will in part determine what remuneration, if any, is deemed appropriate. It is probably fair to say that the frequency and duration of external experience periods will depend very heavily on the ability of institutions to cultivate a large number of potential employers that are able and willing to provide temporary placements for undergraduate students.

Cooperative programmes with up to 50% employment external to the teaching institution used to be, if not common, not altogether unusual. The pre-eminent surviving example would be Michigan's Kettering University, which offers its 2,400 undergraduate students a four-year programme in which they alternate full-time school and full-time work in eight 6-week periods each year. Twenty-four academic weeks a year is not dissimilar to the more normal 26, especially given there are no orientation activities, and a total of 96 weeks' work experience for the programme is impressive. Students almost always stay with one employer throughout their programme.

Part-time study used to be common but is now discouraged, ostensibly so students benefit from a richer student life, but also so academics can lead more normal ones. The basic engineering programme at the Whyalla campus of the University of South Australia (UniSA) used to be a half-time programme over eight years, academic attendance being partly at night, partly by day release. Graduates were thoroughly experienced on graduation, but survival of the programme was very much at the whim of the major local employer. When most students sought other employment on graduation, the employer's patience ran out and they pulled the plug. The company's existing engineers complained bitterly about the loss of a really useful category of worker once there were no more trainees, which demonstrates that suitably employed students are not necessarily a liability to the sponsoring organisation. In fact, it is one of the keys to establishing a good network of cooperating employers to convince them that employing students can be profitable in real terms.

In Australia, the relevant professional institution is the IEAust and its requirement is for at least 12 weeks' experience [5]. Difficulties in placing students have led many institutions to seek relief from even this none-too-demanding stipulation. Currently, students can satisfy the requirement by two periods of six weeks, one of which can be employment of almost any kind. It is assumed that low level employment, such as stocking supermarket shelves, will impart competence in communication, the ability to work in teams, etc. Since this claim has not been tested, it remains a speculation at best and a cop-out at worst.

At the UniSA, the current work experience requirements for engineering students have been formulated largely to accommodate such variations. There is no provision for prior

agreement on objectives between the employer, the student and the university, and, therefore, the outcomes are ultimately untestable. Fortunately the major methods of enhancing the work readiness of Electrical and Information Engineering (EIE) graduates are not dependent upon the outcomes of the compulsory experience period. In this context, in the author's opinion, engineering experience is *not* only to be found in engineering organisations, and a proper systems approach to planning and evaluating the experience, as well as the forging of detailed individual tripartite agreements, will yield manifold improvement in the outcomes obtained. In saying this, however, if work experience episodes are to be offered as competences in the formation of an experienced engineer by the IEAust or similar qualifying body (see below), the verification by a chartered engineer will be necessary.

Worthy of special note are two contrasting responses to the IEAust's requirement, that of the University of Technology, Sydney (UTS) and that of the Flinders University of South Australia.

The UTS has a strong background in cooperative education and uses the IEAust requirement as a springboard for a much more comprehensive experience. Students undertake two semesters of external practical experience *in addition to* their eight semesters of coursework. Students are subjected to a preparatory course of instruction before going on their work placement and undertake formal reflection after it is completed. Successful students gain the additional qualification of Diploma of Engineering Practice (DipEngPrac). Because close attention is paid to the development of anticipated outcomes at the beginning, and achievement is monitored at the end, variability is reduced and the structure adds value to the experience.

The response goes further. The IEAust requires graduate engineers to demonstrate the achievement of so-called Stage 2 competences, normally acquired over three years following graduation, before they can be regarded as *Experienced Engineers* and qualify for the designation *Chartered Professional Engineer* (CPEng). The UTS benchmarked its cooperative students with the cooperation of the IEAust's chief assessor, and many students were accepted as qualifying immediately on graduation. Others were given status for some of the Stage 2 competences. Still others received nothing. It remains necessary for students on placement to take responsibility if the best outcomes are to be achieved [6].

In direct contrast, Flinders began with a programme structure (inherited from the UniSA, with whom they briefly shared a joint faculty during their start-up phase) in which one period of at least 20 weeks' practical experience *replaced* one of the eight taught semesters. It was argued that the combination achieved as much in the formation of qualified graduates as eight normal semesters plus the compulsory 12 weeks' work experience. How so? Again, the emphasis was on structure. Students were exposed to preparatory material to help them win a job and function in it. Academic staff visited students in their workplace twice during the period. Twice during the period, students were required to return to the University for further guest lectures on a variety of topics related to the integration of engineering efforts into the wider commercial world and to society at large. Students submitted papers on selected guest lectures, prepared preliminary and final reports, and gave oral presentations to staff, employer representatives and their peers. The entire exercise was graded. Eight objectives for students were listed, matched by a list of eight benefits for employers. While subject to refinement, these provided – and still provide – the criteria against which the success of a placement can be gauged; these are listed in Tables 1 and 2.

Table 1: Student objectives.

Students will be enabled to:
• Apply skills and knowledge already acquired in their course; • Acquire new theoretical and practical skills associated with the planning, investigation, design, simulation, construction, testing, evaluation, operation or maintenance of engineering systems, equipment or devices; • Appreciate the responsibilities, roles, attitudes, values, priorities, judgements and work methods of practising engineers in industry; • Appreciate the overall manner in which engineering is practised and managed; • Participate as a member of the engineering team; • Understand the roles and value of all members of that team, including professional engineers, other professionals, engineering associates, and technical and support staff; • Gain an understanding of quality assurance processes; • Further develop their own professional attitudes, and reconcile the obligations, responsibilities and actions of professional engineers with their own values.

Table 2: Employer benefits.

Employers will benefit by:
• Valuable contributions made by students to given projects; • Recognition by the engineering profession of their role in the education and development of the next generation of engineers; • Access to students who possess skills not present within the company; • An opportunity to reflect on their own work practices; • The opportunity to preview prospective employees; • An opportunity to sponsor final-year student projects; • Preferential access to staff and facilities within the university; • Opportunities to initiate and undertake collaborative industrial research and development projects with university staff.

The Flinders programme won an IEAust Engineering Excellence award – somewhat to the chagrin of UniSA colleagues – but has since been subject to administrative pressures that have arguably reduced its effectiveness. There was pressure to reduce the period of the experience to a normal semester length in order to facilitate the reporting of results. Understandably, the IEAust did not consent to this. The compromise reached was to complete assessment partway through the work experience. Far from welcoming an opportunity to be part of a similar IEAust benchmarking exercise to the UTS, a complete cohort of students failed to submit so much as one situation report – because it was not compulsory. Even previously compulsory assessable papers on guest lecture topics have now been abandoned as a sop to students' claims of being overworked. Some of them are. Not all employers pay and students work at their night jobs as well as during the day to meet living expenses.

ASSESSMENT OF THE PRACTICUM

It is common for academics to comment on the transformation wrought in students by their industrial placement. If this can be observed, then at least conceptually the various dimensions of the change should be amenable to measurement. Hence, assessment of work experience is theoretically justified. Establishing clear objectives will help in determining the identification and weighting of what is to be assessed and the appropriate methods for doing so. However, because ultimately work experience is largely unmediated, there are, and will continue to be, significant differences in students' *opportunities* for exercising both technical and generic abilities and skills in their work environment. Thus, *grading* the practicum raises serious issues of equity.

IN-HOUSE INITIATIVES

The UniSA has moved from being the only South Australian university incorporating cooperative education in its engineering programmes to one in which external work experience is limited to the IEAust minimum requirements. On the other hand, strenuous efforts have been devoted to structuring in-house activities that foster the development of more relevant technical knowledge and encourage the growth of generic skills. Many of these have been reported elsewhere. These include, but are not limited to, the following:

- Forming strategic partnerships with advanced technology organisations in which the EIE provides tailored short courses at an advanced level in exchange for access to current-technology sites and cutting-edge simulation software [7];
- Having students mimic professional consulting and scholastic activities through the formation of in-house consulting units, student-run conferences for the dissemination of project findings, etc [8];
- Vigorously pursuing sponsorship for, and associated industry involvement in, final year projects [9];
- Extending experiential learning and relating teaching to actual applications throughout the programme [10];
- Encouraging student participation in external events, eg the international Students in Free Enterprise (SIFE) competition (EIE teams won the 2005 and 2006 Australian rounds);
- Creating a large network of adjunct staff capable of providing up-to-date industry perspectives through guest lectures and whole-of-course responsibility;
- Embracing student-based learning with its emphasis on developing self-reliance in acquiring and applying knowledge [11].

In addition, in 2006, the UniSA's engineering schools introduced a sequence of modules embedded in normal courses that seek to systematically develop career management skills [12]. This can be compared and contrasted with the more specific preparatory activities at the UTS and Flinders, for example. The evaluation was disappointing in some respects, mainly concerned with the timing in the programme of various elements (the need to bring forward components because students actually engaged in employment during their programme) and the inappropriateness of using regular lecture slots because the rooms allocated were not suitable for interactive sessions. There were also cultural issues, with many students reluctant to contribute and others unmotivated.

CONCLUSIONS

Rather than leave it to chance, or the vagaries of an unmediated work experience period, it is necessary to plan the activities that will equip engineering students with relevant technical and non-technical skills which will make them prime candidates for the best jobs on graduation. This will include in-house activities, but will also embrace a period of work experience external to the university. However, it is not necessarily clear that employers have enough understanding of the content of contemporary engineering programmes to be able to assess work experience applicants over the full range of their abilities; or to see the mutual benefits that would flow by forming a training schedule and agreement based on specific learning objectives and performance criteria. There need to be stronger efforts by academics to communicate those objectives to both students and employers. Provided the objectives are agreed to and met, there should no longer be an issue about confining work experience or part thereof to an engineering organisation per se. On the other hand, employment not meeting the objectives would be excluded.

Further investigation into the characteristics sought by employers and structures to promote the work readiness of graduates by institutions is planned.

REFERENCES

1. Gernet, J., *Ancient China*. London: Faber & Faber, 113-125 (1968).
2. Chambers's Encyclopaedia, University. London: International Learning Systems, 14, 165-174 (1970).
3. Defence Systems Management College, *Systems Engineering Fundamentals*, Fort Belvoir: Defence Systems Management College, 57 (1999).
4. Institution of Engineers Australia (IEAust), Manual for the Accreditation of Engineering Programs. Canberra: IEAust (1999).
5. McDermott, K.J., Nafalski, A. and Göl, Ö., Quality assurance of engineering programmes through professional accreditation. *Proc 7th Baltic Region Seminar on Engng. Educ.*, St Petersburg, Russia, 199-201 (2003).
6. Johnston, S., Taylor, E., and Chappel, A., UTS engineering internships: a model for active work place learning, *Proc. Inter. Conf. on Engng. Educ.*, Oslo, Norway, 7B6-16 (2001).
7. Nafalski, A., McDermott, K.J. and Göl, Ö., Teaching of computational electromagnetics in electrical engineering programmes. *Proc 9th UICEE Annual Conf. on Engng. Educ.*, Muscat, Oman, 39-42 (2006).
8. Nafalski, A., McDermott, K.J., Koronios, A. and Göl, Ö., Industry schemes in engineering and computer science education. *Proc 9th UICEE Annual Conf. on Engng. Educ.*, Muscat, Oman, 187-190 (2006).
9. Göl, Ö., Nafalski, A. and McDermott, K., The role of industry-inspired projects in engineering education. *Proc. Frontiers in Educ. Conf.*, Reno, USA, 2, F3E-1-4 (2001).
10. Kolb, D., *Experiential Learning: Experience as the Source for Learning and Development*. Englewood Cliffs: Prentice-Hall (1984).
11. Woods, D., *Problem-Based Learning: How to Gain the Most from PBL*. Hamilton: McMaster University (1994).
12. Berry, E., A Holistic Approach to Integrating Careers into the Curriculum. Flexible Learning Centre internal document, Adelaide: University of South Australia (2006).