Improving Industry Engagement in Engineering Degrees

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Structured Abstract

BACKGROUND
During the latter half of the twentieth century, the focus and content of formative engineering degrees that qualify graduates to commence supervised practice progressively emphasised engineering science, somewhat at the expense of its connections to engineering practice. Australian engineering degrees, nevertheless, have long included requirements for industry exposure, to round out and contextualise students' engineering science and application knowledge, and provide experience relevant to their future practice as graduate employees. The quality of students' exposure to industry has become more variable as engineering enrolments have increased and diversified, industries' structures and employers' expectations have changed, and the academic workforce has become more focussed on engineering science research. The changes present new challenges in coverage, quality, and assessment (by the universities) of students' experience of industry engagement.

PURPOSE
This paper describes a major national project completed in June 2014 by the Australian Council of Engineering Deans, and funded directly by government. It aimed to improve industry engagement in Australian formative professional engineering degrees. The working hypothesis was that student retention and graduation rates, and graduates' employability could be increased by stronger industry engagement for all students, particularly in the early years of engineering degree programs.

APPROACH
The two-year project was led and managed by the authors. The project involved a large, representative set of the 35 Australian universities that provide engineering degrees, and was supported by Engineers Australia, industry peak bodies, and many engineering employers. Two distinct approaches were taken. The first developed a research-based model for improved industry engagement in engineering degrees, and refined this in extensive sector-wide consultation processes. The university participants explored their own practices, and plans against this model. In the second approach, seven universities developed, implemented, and evaluated 'industry-inspired' content, mostly in large enrolment subject units in core curriculum areas of engineering science and practice. This content involved about 30 engineering employers, and was taken by about 1,000 students.

RESULTS
The deliverables from the first approach are model principles for an industry engaged curriculum, expressed in the forms of best-practice guidelines, and recommendations for action by academic providers, industry and employers, and sector wide stakeholders, including government. These are complemented with a suite of resources, including a reflection tool for universities to assess their performance against the model. The participating universities have all demonstrated or planned practice improvements in their industry engagement methodologies. From the second approach, the industry-inspired projects have been packaged with materials and project notes for other engineering educators to use. Internal evaluations of these projects have indicated positive impacts on learning.

CONCLUSIONS
This project has contributed directly to continuing improvement in engineering education, and national accreditation and engineering skills development. The work aligns with national interest in the benefits of workplace integrated learning (WIL) in higher education, particularly in science, technology and mathematics, building on the experience of engineering.

KEYWORDS
Industry engagement, workplace learning, engineering education, authentic curricula

Introduction

The last national report on engineering education in Australia (King, 2008) raised concerns about the excessive engineering science content and/or its detachment from practice, in formative professional engineering degrees. These programs qualify graduates to commence supervised practice. Most Australian engineering degrees have since inception, included requirements for industry exposure, that respond to the criteria for program accreditation set by Engineers Australia (2014). Almost all universities require their students to gain 12 weeks' industry experience, mostly as a zero-credit requirement, prior to commencement of their final year of study, but few integrate this strongly into the taught curriculum. Most engineering programs also include guest lectures and allow students to take an industry-based capstone project. The effectiveness of these and other industry engagement has not been systematically researched.

Several factors are now impacting on the provision of industry engagement within formative degrees. These include the growth and increased diversity of enrolments, changing industry structures and employment conditions, and increased employer expectations, often expressed in terms of 'job readiness'. Simultaneously, the engineering academic workforce has become more focussed on engineering science research, and its new members typically have limited engineering practice experience, other than in research. These factors all present challenges in coverage, quality, and assessment (by the universities) of students' experience of industry engagement. The quality of exposure to engineering practice gained by students on engineering degree programs in Australia has become less consistent.

The work described in the paper aims to provide evidence and material to assist the engineering education sector and its stakeholders to increase curriculum focus on engineering practice. This will strengthen the curriculum, increasing students' perception of relevance of the engineering sciences, improve graduate outcomes for employment, and prospectively, increase enrolments into engineering. By adopting the findings of the work described, universities will bring more contemporary industry experience into the curriculum, as well as improve the roles and implementation of industry placements, that profession and industry stakeholders wish to remain as a core feature of Australian engineering degrees.

Best-practice Guidelines for Industry Engagement

With already crowded formative engineering degree curricula, recommendations for change to incorporate stronger industry engagement need to be based on evidence. In this project, evidence of current practice and directions for change were developed progressively from literature, survey research and extensive consultation with relevant stakeholders, including employers, students, academics, and representatives of the engineering profession. The methodology also sought to identify examples of best practice, so as to encourage their adoption elsewhere.

Research Questions and Methodology

Seven research questions shaped the study:

1. What is the ideal student experience of industry engagement?
2. What is current practice?
3. What is the current student experience?
4. How does this differ from ideal?
5. What are potential benefits for other stakeholders?
6. What are supporting and risk factors?
7. How can engagement be improved?

Questions 2 and 3 recognise that there are inevitably differences between the 'intended', 'enacted' and 'experienced' curricula as noted by Billett (2011). Question 2 refers to the intended and enacted curriculum and Question 3 refers to the experienced curriculum.

Questions 2, 5, and 6 were addressed by collecting data about current practices from personnel involved in industry engagement in engineering education in universities and industry. The student experience, identified by Q3, was understood through focus groups with students, and a student survey which also provides a baseline for monitoring future progress. The answers to Q1 informed the development of the model for effective exposure that was grounded in the literature (see below). In addressing questions Q4 and 7 participants and the researchers could compare current practices with this model, as well as express their aspirations for improvements.

The draft Best-Practice Guidelines (including recommendations for the faculties, industry and other stakeholders) were developed iteratively over the course of the project as the interviews with university and industry members continued, and focus groups were held with engineering students. The findings from these were not intended to be generalisable, as they relate to the experiences of individuals and provide expression of diversity of perceptions and practice. The inclusion of material in the final documents was therefore negotiated through discussion and at testing at project forums. Further details are below. Human research ethics approval was obtained. Studies undertaken by six final year students also contributed to the research.

The following paragraphs summarise each of the research study methods.

A survey of 16 universities profiled current industry engagement methods and contributed to addressing Q2. Participants rated the extent of their use of the methods for industry exposure listed in the Engineers Australia program accreditation guidelines. The survey was undertaken on paper and then followed up by interview. (The sample universities were from every state and territory, and included all five members of the Australian Technology Network, four of the Group of Eight, two from the Innovative Research Universities group, two in the Regional Universities Network, and three others.) Each was represented by its dean, associate dean, or an individual with good knowledge of the engineering programs.

In-depth interviews were conducted with 55 informed stakeholders (from industry, the faculties and the profession) particularly to identify examples of effective practice. The range of industry roles was wide, including engineers, engineering managers, human resource managers, engagement managers, and chief executive officers. From the faculties, there were academics, industry liaison managers, internship program managers, and a mentoring program manager. The industry engagement initiatives with which they were familiar were compared with the model, and enablers, benefits, and barriers were identified.

Three focus groups, including 30 students in total were held at different universities during 2013. The students were asked about the most valuable exposure to engineering practice or engagement with industry in their engineering education so far. Follow-up questions were shaped by the evolving model of effective exposure to practice.

Industry-university forums were held in Sydney, Melbourne, Brisbane, Adelaide and Perth in June 2013, with 149 attendees. These discussed the draft Guidelines, and informed their subsequent revision..

A survey of engineering students was undertaken in 2014. Valid responses were received from 231 students and 215 of these responses were from final-year bachelors or masters students. Results reported below are based on analysis of these 215 responses.

Findings

The curriculum model that integrates effective exposure to engineering practice in engineering degrees was developed progressively from the study findings, and the literature on engineering education and higher education. The literature identified perceived capability gaps (King, 2008; Male, Bush, & Chapman, 2010; Spinks, Silburn, & Birchall, 2006), engineering as socio-technical activity (Trevelyan, 2010), accidental competency formation (Walther & Radcliffe, 2007), potential misperceptions (e.g. Faulkner, 2007), graduate transition into practice (Wise, Schutz, Healy, & Fitzpatrick, 2011), identity formation (Blandin, 2012) and learning through participation (Johri & Olds, 2011), reflective practice (Kelly & Dansie, 2012; Orrell, 2011; Raelin, 2007), motivation to learn (Male, 2012) and improved learning of troublesome concepts (Perkins, 1999). The model encompasses students' whole education experience of learning, motivation and identity development (Figure 1).

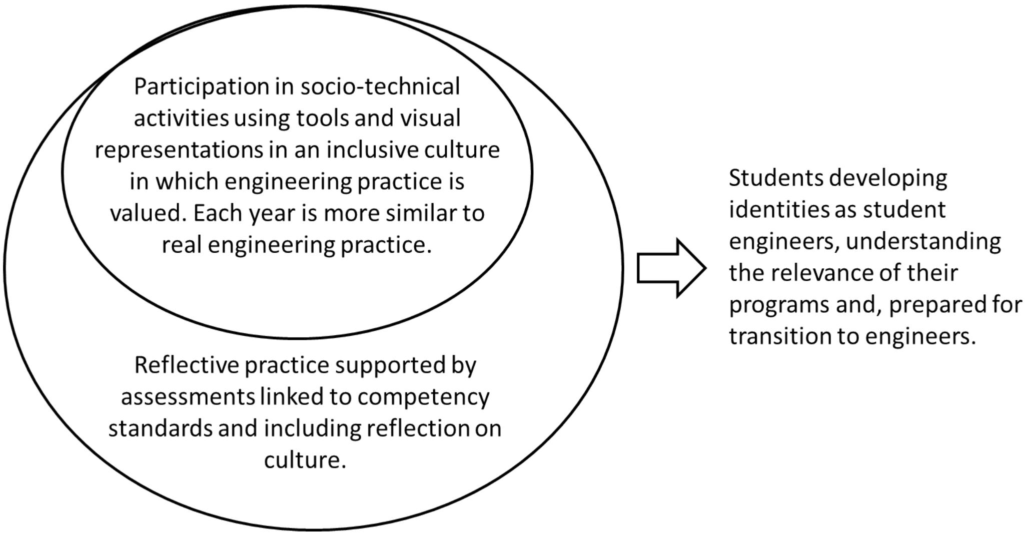

Figure 1: Model of effective exposure to engineering practice in an engineering degree

Exposure to practice in the curriculum is thus designed to support students to develop:

- more comprehensive and accurate understanding of engineering practice;
- a sense of belonging to the faculty and the profession;
- motivation for learning from recognition of relevance of the engineering program;
- improved learning through understanding context and connections.

The survey of universities revealed many strong initiatives and considerable diversity, related to location, age, size, and level of specialisation. Academics reported transformations that can occur when students are exposed to practice. However, a dearth of exposure in the middle years of programs was confirmed, and participants reported that many of the best initiatives in place were limited to a select group of students.

Students' experiences of initiatives confirmed their variability. Positively transformational experiences of 12 weeks (or longer) industry experience were described by many students, in terms of development of many competencies, confidence, realisation that there was much to be learned, and discovery that they did not need to know everything. Despite some outstanding examples of internship and sandwich programs, student employment and experience programs were also reported as 'mundane', and poorly monitored and assessed. Discouraging guest speakers were also referred to. Reflective practice, identified as critical in the model, was found to be outstanding at some universities but more often severely limited in the assistance, motivation, and assessment provided to students.

The results of the student survey provide a tool and baseline for tracking future progress. The types of industry engagement rated by at least 60 (28%) of the 215 students as having significantly increased their understanding of engineering practice were:

- 12 weeks of vacation engineering employment or equivalent part-time engineering work;
- guest lectures;
- engineering internships of six months or more;
- industry-based final year projects;
- hearing or reading about another student's workplace experience;
- teaching by staff with recent, non-research industry experience;
- industry visits and inspections;
- industry-based case studies;
- problem solving, projects, or evaluation tasks with direct industry input of data and advice.

Two points are of particular note: firstly 74% of the students responding did not indicate agreement with the statement that they had tracked their development towards engineering capabilities; secondly, 29% of the 2014 students in their final year of their bachelor or masters degree had not completed 12 weeks of vacation employment or an internship. These points are referred to later. The student survey indicated opportunities for improvement that are consistent with other data collected in the study. These are addressed in the recommendations for the faculties, industry and professional and industry bodies, and governments in the Best Practice Guidelines developed throughout the project (Table 1).

Interviews with industry personnel revealed willingness to engage with universities. Benefits to organisations (and their engineers) from engaging with engineering education are critical to gaining the further support of industry. Reported benefits included:

- greater visibility and loyalty among students and graduates, who become their future employees, clients, contractors and alliance partners;
- enhancement of their organisation's brand among these future engineers;
- improved accuracy of perceptions about working for the organisation held by prospective graduate recruits, thereby improving their retention (in employment);
- opportunities to work with future graduates, identify potential graduate recruits, and influence the capabilities of future graduates;
- opportunities for professional development for staff through the experience of engaging with students, which appeals to the organisation's employees, and provides personal satisfaction;
- enhancement of the social licence for the organisation (in the community);
- development of relationships with university researchers leading to future collaborations;
- access to university resources such as laboratories, libraries, and experts.

Common reasons reported for not engaging were the lack of any university approach, and difficulties in finding ways to be engaged. Employers strongly encouraged universities to contact them about opportunities, and provide examples of recent successful engagement.

Table 1: Recommendations for Best-Practice Industry Engagement

Recommendations for the Faculties	
F1	All engineering faculties will establish and maintain effective industry engagement as part of faculty culture [with] a) people, processes, and resources to ensure strong relationships with industry b) *structural and developmental support for academics to engage with industry* c) engineers [academics] with industry experience in facilitating learning d) structured and transparent industry consultation
F2	All engineering faculties will use industry-based assignments
F3	All engineering faculties will provide substantial opportunities for students to work and learn in industry...
F4	High percentages of students will have opportunities to undertake industry-based final year (capstone) projects
F5	Emulated work-integrated learning will be developed as an example of effective industry engagement
F6	Students will be encouraged to take responsibility for seeking opportunities to learn about engineering practice
F7	Engineering faculties will support and recognise industry engagement undertaken by student groups
Recommendations for Industry	
I1	Organisations should provide regular and structured student engineer employment
I2	Engineering employers should provide support for their engineers to engage with engineering education
I3	Engineering employers should provide support for academics to experience industry
Recommendations for Professional and Industry Bodies, and Governments	
B1	Industry bodies, universities, student societies, and the Australasian Association for Engineering Education, should consider establishing a resource centre to support industry engagement with universities
B2	Government, professional bodies, and engineering faculties should consider establishing a joint internship scheme
B3	Engineers Australia should consider developing an e-portfolio resource for student engineers
B4	Industry bodies should foster a culture of industry engagement with education
B5	Government should consider incentives for employers to support engineering education
B6	The engineering program accreditation board should review the accreditation guidelines with respect to [strengthening] exposure to engineering practice

Finalisation of the Best-Practice Guidelines and related deliverables

The Guidelines were developed progressively from the study findings referred to above, inputs from a workshop at the 2013 AAEE Conference, and the Australian Council of Engineering Deans (ACED) in April 2014. They were finalised with advice from the project partners and project Reference Group. The Guidelines elaborate the curriculum model and list the benefits to industry as described above.

The bulk of the Guidelines document is the recommendations, each elaborated and illustrated with summaries and links to best-practice examples, and other related resources. All of these are available on the Engineering and ICT education resource website (www.arneia.edu.au). They demonstrate that there are many solutions to the issue of industry engagement in engineering degrees. Indeed, a major finding of the project forums was to recognise the diversity of employers, programs, and students. To assist universities assess the strengths and weaknesses of their programs and systems with respect to industry engagement, a 'reflection tool' (in the form of a checklist) was developed. This tool is included in the project resources, together with a benchmark document compiled from the project partner universities' initial responses.

Industry-Inspired Content in Core Engineering Subjects

Alongside the development of the Guidelines, seven universities were each provided with modest funding (up to about $20,000) to develop, implement and evaluate 'industry-inspired' content within one or more core engineering course units. The term 'industry-inspired' has been adopted here to reflect the wide range of ways the industry input was ultimately adopted within the curriculum.

Approach

The intention of most of the content that was developed aligned directly with the desire of the government funding body to reduce attrition from engineering degrees. Previous work (Godfrey & King, 2011) found that significant attrition occurs when students engage poorly with difficult core engineering science material during the middle years of their degree programs. Students likely to fail typically may see this content as 'highly theoretical' and not clearly related to (what they perceive to be) engineering practice. The participating universities were invited to propose topics with direct industry input that would prospectively enhance students' learning and could be incorporated into an existing course unit. The latter constraint was necessary because the funded project duration would clearly not allow for faculty and university approval of major course changes or the introduction of new courses.

The range of supported content is listed in Table 2. It is evident from the list that three universities chose to develop industry-inspired material in project engineering and the related area of risk assessment, rather than in engineering science. This was acceptable, given broad industry concerns with graduates' knowledge and competencies in these areas. One participant explored having students interview industry-based engineers, and another developed a complex case-study; interestingly both of these methods are being generally under-exploited in formative engineering programs. The Electrical Plant course had students undertake an energy audit with real data, a practical task that some students found quite challenging.

Approximately 30 engineering companies were involved in developing and implementing the content, and more than 1,000 students have taken the course units with the industry inspired content, some in very large classes. The educational experience was evaluated using student questionnaires in all participating faculties. In addition, the project work undertaken by two participants was further assessed by an external evaluator.

Table 2: Industry-inspired content in core engineering course units

University	Course, Year, Trialled, Students	Industry Partners
Australian Maritime College (University of Tasmania)	Project Engineering, Yr 2 Semester 2, 2013, 93 students in three disciplines	16 individuals from 13 companies: Apache Corp., Atkins Global, Chevron, Crondall Energy, Exoduc Group, McDermott, One Sub Sea, Peritus Int., Saipem, SubSea 7, Technip, Wood Group Kenny, Woodside
Deakin University	Power Systems Design, Yr 2 Semester 2 2013, 100 students	SPNet
James Cook University (JCU)	Engineering Project Management, Yr 3 Semester 1 2013, 80 – 90 students Semester 1 2014	Rockfield Technologies Glencore-Xstrata Copper
University of South Australia	1) Power Systems Analysis, Yr 3 Semester 2 2013, 42 students 2) Engineering Dynamics, Yr 2 Semester 2 2013, 130 students Semester 1 2014, 23 students (including Open Universities Australia) 3) Fluid Dynamics, Yr 2 Semester 2, 2014	PSD Energy Arrium Mining and Materials/ One Steel Arrium Mining and Materials/ One Steel
University of Southern Queensland	Electrical Plant, Yr 3 Semester 1, 2014, 110 students	Downey Engineering
University of Technology, Sydney	Mechanics of Solids, Yr 2 Semester 2, 2013, 274 students	Atlantis, Sika Australia, Geofabrics, Arup, SMEC, Lend Lease
The University of Western Australia	Risk, Reliability & Safety, Yrs 4/5 Semester 1, 2014, 186 students	Rio Tinto Iron Ore

Results

The student's evaluations indicated their appreciation of the relevance of industry-inspired content, and opportunities to meet industry-based engineers. The evaluations also indicated that students perceived that through the industry-inspired content:

- they improved their understanding of engineering concepts;
- they improved their understanding of the relevance of their units, and their motivation;
- they developed skills that will be important in the workplace such as analysis, problem solving, ability to use software tools, ability to read documents and standards, communication, and teamwork.

For the case of JCU, the external evaluator reported that '*student teams are poised to deliver very professional outcomes, with diverse proposals that will compare interestingly with the live project result*'. He reported initial feedback from the students as '*high level of satisfaction and outstanding benefits from working in a multidisciplinary environment and using a real industry project to develop and test the application of knowledge and skills'.*

The universities found companies and engineers willing to share non-critical engineering materials and data, and spend time in the classroom. Academics demonstrated adaptability required to build such content into it into existing course units, at fairly short notice. All participants will continue to use the materials developed and make it available to others, in some cases in modified form. They also reported on the practical challenges, and confirmed that for success, a small earmarked grant is highly desirable, if not essential, to support the development of the industry relationship and the materials.

Discussion and Conclusions

The project described here originated within a government program on engineering skills shortages, yet was conducted during a time of increasing engineer unemployment. The approach taken by the project team sidestepped (but did not ignore) employment trends, by focussing on how to systematically improve industry engagement for all students, and thereby improve retention and graduate rates, and graduates' employability. These data are likely to be tracked by individual universities as part of their performance indicators.

The research undertaken provided evidence of constructive thinking, good practice, and deficiencies in current practice. Adopting the Best-Practice Guidelines will support improvements, not least by rethinking engineering education from the perspective of practice as well as science. The recently published report by the Australian Workforce and Productivity Agency on engineering skills (AWPA, 2014), has recommended that further work in this area be undertaken, based on the present project.

Whilst the universities design and operate their programs independently, their graduates are employed globally; more than one third of the 10,500 graduates from formative professional engineering programs in 2012 were not Australians. The issues examined in the project are thus of global interest. The prime mediator between the engineering faculties and engineering employment is the program accreditation system operated by Engineers Australia (EA), and its Stage 1 Competency standard (EA, 2014). This has been an important reference point for the project, and the involvement of EA officers has been critical.

The Australian Council of Engineering Deans, AAEE and senior EA officers have established a working party to define specifications for an e-portfolio to be used by engineering students across the country to track their progress against the competency standard. EA also launched in 2014, a national online resource, EA Connect, to assist students to contact employers willing to offer industry placements.

This resource is likely to be especially valuable when set alongside the impact of structural changes in the major industry sectors in which engineers are employed, namely manufacturing, infrastructure (public and private), and resources. Over the project period, difficulties of securing student placements became increasingly evident from discussions at industry-university forums and from the student focus groups. The historical expectation that engineering students have paid work experience placements is clearly under threat. Many universities, and others, are examining ways in which work experience (under the banner of work integrated learning – WIL) can be provided systematically within the curriculum, but outside the traditional casual employment arrangements favoured by engineering faculties. The findings and Guidelines developed in this project are contributing to the discussion on the benefits and operation of WIL in science, technology and mathematics degrees.

The successful trial of bringing industry-inspired content into the curriculum demonstrates the power of small and focussed investment, and has potential further benefits for university–industry partnerships. It is not hard to envision each university contributing to a substantial resource of industry-inspired and industry-referenced materials in all core course units in engineering science and practice. The significant cultural challenge for the engineering education sector is for academics to use others' material, rather than reinvent their own.

Improving the quality of industry engagement of engineering students will continue to be work in progress, demanding the attention of all stakeholders. The study reported here and its outcomes have highlighted both deficiencies and challenges to current practice, and many opportunities for systematic improvement.

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