Best Practice Guidelines for Effective Industry Engagement in Australian Engineering Degrees

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Preamble

These draft guidelines are an outcome of the project 'Enhancing Industry Engagement in Engineering Degrees' led by Australian Council of Engineering Deans with a grant from the Australian Government through the National Resources Sector Workforce Strategy. The project has 12 partner universities and also industry partners: Engineers Australia; Minerals Council of Australia; Australian Mines and Metals Association; Consult Australia; Australian Constructors Association; and the Australian Petroleum, Production and Exploration Association.

The guidelines apply to 'formative' degree programs that prepare graduates to enter engineering practice as professional engineers or engineering technologists. The relevant qualification for the former occupation is a 4-year Bachelor of Engineering degree, although some universities are now offering formative Master of Engineering degrees. Engineering technologists graduate from 3-year Bachelor of Engineering Technology programs. Programs are accredited by Engineers Australia if they deliver graduates with the Stage 1 Competencies for the corresponding occupation and are compliant with other accreditation criteria. One of these is that within their program, graduates have 'exposure to engineering practice'.

The guidelines are informed by literature, consultation with Engineers Australia, a survey of the 12 partner universities and five additional universities, and interviews or focus groups with over 80 participants including academics, industry members, and students. The guidelines have been revised following review by 149 industry members and academics at five forums in Sydney, Melbourne, Brisbane, Adelaide and Perth in June 2013. Recommendations will be trialled in second semester 2013 and first semester 2014.

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Introduction

Problem

There is a skills shortage in engineering in Australia (The Senate, 2012). Engineering graduates are employed in engineering roles, and gain experience prior to being recognised as skilled and independent engineering practitioners. The average graduation rate of students who commence study in engineering bachelors degrees in Australian universities is about 65% (Godfrey & King, 2011), a figure that suggests scope for improvement. Furthermore, those student engineers who do graduate have significant gaps between their capabilities and those required by engineers in practice (Male, 2010b). Exacerbating the engineering skills shortage, many engineering graduates choose not to work in engineering-related roles (Tilli & Trevelyan, 2010).

Background

This project is intended to contribute to reducing the engineering skills shortage by acting on the proposition that improving students' engagement with engineering practice will increase graduation rates and graduate employability. Participants in this study resoundingly reported that exposure to engineering practice is transformative.

However, engineering practice is poorly understood (Trevelyan & Tilli, 2007) by both students and their academic teachers. At many Australian universities there are few academics with recent industry experience(Cameron & Reidsema, 2011). Despite the efforts of many educators, engineering education is largely shaped by a focus on engineering science (Sheppard, Macatangay, Colby, & Sullivan, 2009), rather than applications and practice. Consequently, before any substantial exposure to practice, students are expected to learn theory without context or relevance. Many students find this difficult and not highly motivating to their learning. Furthermore this approach does not reinforce the breadth of capabilities necessary for engineering practice, particularly its critical socio-technical dimensions (Faulkner, 2007; Fletcher, 1999). As a result, students are likely to have misperceptions about engineering practice, and develop professional identities that are inconsistent with practice.

Industry engagement within engineering education offers potential to help students prepare for and transition into graduate employment. Specifically, stronger industry engagement will assist students to:

- develop more comprehensive and accurate understanding of engineering practice as a socio-technical activity;
- develop motivation for learning due to recognition of relevance of the engineering program and the value of engineering;
- improve learning through understanding context and connections;
- develop reflective practice skills to improve learning and support lifelong learning;
- develop comprehensive socio-technical capabilities;
- develop a sense of belonging to the faculty and the profession
- build networks.

Industry participants in this study reported that by engaging with engineering education they have experienced:

- visibility and loyalty among students and graduates who become future employees, clients, contractors, alliance partners, etc., and

    - enhancement of their organisation brand among these future engineers
    - improved accuracy of perceptions about working for the organisation held by prospective graduate recruits, , thereby improving their retention
- opportunities to work with future graduates and to identify potential graduate recruits
- opportunities to influence the capabilities of future graduates
- opportunities for professional development for staff through the experience of engaging with students
- personal satisfaction for those engaged in working with students
- appeal to the organisation's employees
- social licence for the organisation
- development of relationships with university researchers leading to future collaborations
- access to university resources such as laboratories, libraries, and experts.

These guidelines are intended to strengthen the culture of industry engagement in engineering educationin Australia. They have been designed with an acute awareness of diversity of all aspects of engagement. The engineering faculties and schools in the 33 Australian universities that provide formative engineering degrees are diverse in size, focus, and student and academic demographics. Furthermore, these change with time. Additionally, 'industry' engaging with engineering education can include: government, private, government business, research, and charity organisations; large, small and medium organisations; professional societies and organisations; and individuals. Industry partners are very diverse and have changing needs. Many are 'resource light' in terms of their ability to run comprehensive human resource departments or 'talent management' programs. Amongst the 33 universities are features of effective models of industry engagement, including high levels of staff with industry experience and well-established internship schemes.

Aims and Scope

These guidelines are aimed at supporting engineering schools to provide improved industry engagement for ALL student engineers in a formative degree program. Thus, these guidelines are intended to promote existing good practice across the system as a whole and are consistent with – and effectively expand upon – the current expectations of Engineers Australia in program accreditation (Accreditation Management System, EA, 2012). The full adoption of these guidelines will represent more significant change in some universities than others. Recognising that the environments in which universities operate can limit capacity to achieve desirable goals, the guidelines present opportunities for universities to differentiate themselves by focussing on the adoption of particular areas of the recommendations. The guidelines are also based on the underlying assumptions that much can be learned about practice whilst at university and that successful graduates will continue to learn throughout their careers.

Vision

Engineering education provides students with the best possible opportunities to develop competencies (knowledge, skills, attitudes) and opportunities to underpin successful lives as engineers contributing to a well-functioning society ((Rychen & Salganik, 2003) adapted by Male (2010a)). Engineering graduates will contribute to the economy and to improving workplaces, industry, the environment and the general well-being of society, locally and globally.

This project will contribute to this vision by establishing industry engagement in formative engineering degrees as a key part of the culture of all engineering faculties and their partnerships with employers. This will support students to progress through their programs and prepare them for their transition to engineering practice.

By engaging in authentic engineering problems, solutions, practices and roles, students will be more highly motivated to their studies, and will:

1. improve their understanding of the concepts, tools and applications of engineering science and fundamental mathematics and sciences;
2. comprehend the relevance of socio-technical competencies;
3. develop the desired attitudes for engineering practice;
4. develop their identities as student engineers, and develop self-efficacy to achieve their goals;
5. develop accurate perceptions of engineering practice, in preparation for the transition to practice.

Curriculum Themes for Improved Exposure to Engineering Practice

To have the impact desired within the faculty, improved exposure to engineering practice needs to be fully integrated into authentic curriculum development and delivery, through adopting the following two broad themes in the design and delivery of the whole formative engineering education experience. Each theme will be realised by the adoption of the elements listed.

Theme 1. Engineering curriculum design and delivery should incorporate the spectrum of local and global engineering practice

- **(a)** Curriculum design is informed by present and prospective engineering practice, including research in engineering practice, engineering applications and engineering science.
- **(b)** Curriculum delivery includes a range of experiences of engineering practice, by positioning theory in its application contexts, by using industry-based examples and projects; and by site visits and guest lectures.
- **(c)** Authentic and substantive challenges requiring contextual understanding ensure students develop judgement, significant technical expertise, teamwork, initiative, and sound practice under mentoring and monitoring arrangements involving professional engineers.
- **(d)** Socio-technical dimensions of the curriculum demonstrate the integrated nature of engineering practice where technology and people interact and engineering knowledge and skills are combined with others' professional and generic skills. For example, student teams should work on technical problems in social contexts, and at least one unit should involve students from a non-engineering discipline that intersects with engineering practice.

(e) Work-based learning is integrated and assessed.

(f) E-portfolios and/or reflective journals are used by students to track the development of their capabilities towards the Engineers Australia Stage 1 and Stage 2 competencies.

(g) Curriculum design and delivery are undertaken by academics recruited and rewarded by processes that acknowledge industry experience and engagement.

Theme 2. Engineering education should incorporate the student's whole experience

(a) Students engage in a participatory experience through which they develop into competent, motivated, professional graduates. Their development is influenced by experiences both within and outside the classroom, encouraged by faculty members and industry practitioners. The student's engineering education experience is framed by being and being treated as a 'student engineer' (e.g., Lindsay, Munt, Rogers, Scott, & Sullivan, 2008).

(b) Students engage in extra-curricular activities that have professional dimensions, e.g. networking events, mentor schemes, careers expos and professional meetings.

(c) Student engineers develop their identities and self-efficacy through gaining confidence in the development of their knowledge and skills, which in turn requires understanding of and confidence in achieving possible future roles.

Recommendations are presented separately for: engineering faculties; industry; and accreditors, Engineers Australia, and government. Brief descriptions of examples of effective practice are included with recommendations. More detailed descriptions of significant examples appear after the recommendations.

Definitions

In these recommendations terms are used as follows.

Engineering practice — The activities undertaken by professional engineers in the course of their work.

> *While the outcomes of engineering generally have physical forms, the work of experienced professional engineers recognises the interaction between people and technology. Professional engineers may conduct research concerned with advancing the science of engineering and with developing new principles and technologies within a broad engineering discipline. Alternatively, they may contribute to the education of engineers, continual improvement in the practice of engineering and to devising and updating the codes and standards that govern it.(Engineers Australia, 2012, p1)*

Industry — Companies, government, engineers, industry bodies/associations, and charities

Internship — Student employment paid or unpaid in an engineering environment, for an extended period longer than three months and commonly six months, commonly undertaken by students during one or more semesters of the engineering program

Program — A course of study from first year to degree completion

Student employment — Internships and/or vacation employment as defined above and below

Unit	A module of study usually taken over one semester. Others might call these ‘papers’, ‘subjects’ or ‘courses’
Vacation employment	Engineering student employment paid or unpaid outside class-time in an engineering environment, commonly at least 12 weeks accumulated before graduation - This could be during vacations or increasingly is undertaken by students on a part-time basis during semester, but is not allocated a semester during the engineering program.

Recommendations for Engineering Faculties

F1. All engineering faculties should establish and maintain effective industry engagement as part of faculty culture.

All engineering faculties should ensure effective industry engagement in engineering degrees. Engineering faculties should establish strengths and weaknesses with respect to these guidelines and plan to implement and evaluate relevant improvements.

F1a. All engineering faculties should establish people, processes, and resources to ensure strong relationships with industry

There should be sincere, respectful relationships between faculty members and members of organisations. An academic position and professional support staff should be allocated responsibility and resources to establish and nurture relationships with industry partners.

Engagement from within the faculty should be co-ordinated using a register, and should be proactively maintained. Human resource managers are important as they can align university engagement with development and priorities in the organisation. It is also valuable to establish a relationship with a key individual who is passionate about engaging with education, is in a role that integrates all of the organisational functions, and has established relationships and credibility across the organisation. This person is well-placed to identify people who have specific expertise and motivate them to engage with education.

Industry contacts should receive regular communication and invitations to events, and annual emails confirming their contact details and availability for engagement in the new year. After engaging, partners should be thanked and consulted about their reflections and suggestions for improvement. When contacts in organisations move, the university should identify a new partner in the organisation.

To assist with establishing initiatives, universities should consider preparing brochures for employers combining recent examples of success, ways organisations can engage in teaching and research, and relevant university contacts. These brochures should include examples of each type of engagement. For example, they could include expectations of vacation employment with examples of recent student experiences, and expectations of industry-based final-year projects with examples (Example 1).

F1b. All engineering faculties should provide structural and developmental support for academics to engage with industry

Faculty leaders should have a clear vision for industry engagement, including expectations of and support for staff, articulated across the faculty.

Activities that contribute to exposing students to engineering practice should be recognised in recruitment, promotion, work-time allocation, resource allocation, and awards.

Engineering faculties should have processes to help academics expose students to engineering practice. These could include networks, events and resources to provide opportunities for engineering teachers to engage with industry, access research in the field of engaging industry in engineering education, and develop knowledge and skills to expose students to engineering practice.

Faculty members should have access to guidelines for main types of industry engagement in engineering education. Examples are vacation employment or internships in engineering organisations, emulated work integrated learning in the university, industry-based individual or team projects, industry-based projects within units, units taught by engineers and with engineering practice integrated into the unit, guest lectures, site visits, lunch-time panels, mentors schemes, and industry expos. Guidelines should be designed to simplify the process; maximise the potential benefits for all stakeholders; and minimise risks to safety, use of resources, cost, and relationships with organisations. All processes engaging industry members should: be respectful of industry members' time; use their experience; and maintain focus on benefits for students, the engineers, and the engineers' organisations.

Student clubs and societies should be supported in their engagement with industry, with guidelines, faculty resources and processes for coordination and professionalism across the faculty.

Current example of effective practice

Support for academics to engage with industry to enhance teaching

Model 1: An engineering department in Australia employed a senior engineer two days per week to teach, and identify industry applications of aspects of the curriculum. He identified site visits for students taking relevant units and for the student association. He also worked with individual academics to introduce them to organisations where the theory they taught was applied so that the academics could then use industry-based examples in their teaching.

Model 2: Academics taught into in-house units for engineers in an industry organisation. The units were approved by the university as units in masters programs. This experience gave academics an opportunity to network with industry members, and learn about industry to inform their teaching and research.

Model 3: Academics involved in a CRC adapted industry-based problems These could be enhanced through photographs, objects, guests, or site visits.

F1c. All engineering faculties should engage engineers with industry experience, in facilitating learning

Engineering faculties should engage industry-members in facilitating students to learn, ensuring that the value of engineers' experience is respected and benefits of this optimised.

Faculty leaders should recognise the contributions of industry-based engineers who facilitate students' learning, with appropriate titles. Facilitators should be well-supported with orientation, office space, and evidence-based guidance.

Industry members should be employed in ways that optimise their experience and minimise their need to adapt. Faculty leaders should consider innovative teaching structures such as block mode, and plan for long-term employment of industry-based teachers. Industry-based learning facilitators, can have roles similar to those in the workplace - perhaps as a mentor, team leader, or client.

Current examples of effective practice

Industry-based engineers engaged in facilitating learning

Model 1: In an Australian university, an organisation was paid to take responsibility for developing and teaching a unit with several senior engineers, graduate engineers, and a human resource manager involved. This model is recommended because remuneration for teaching is not competitive with engineers' remuneration in industry. Under this model, the engineer, the organisation, the university, and the students benefitted. In this case the university provided tutoring and marking. (Example 2 at the end of the recommendations)

Model 2: In an Australian university, an engineer based in a consulting firm developed and taught a unit and the university paid his employer. This model is similar to Model 1 above, except that the individual engineer built the relationship with the university, and gained approval and support from the employer. Longevity of the model would be improved if the organisation committed to maintaining the responsibility in the case of the individual engineer becoming unavailable.

Model 3: In many Australian universities, senior engineers give one or two guest lectures a semester. In one Australian university, a Head of School in a single engineering discipline implemented a policy in which every unit had a prize sponsored by industry and the sponsoring organisation provided a relevant guest lecture every semester the unit was taught. It is important that the quality of guest lectures is monitored in this context.

Model 4: In an Australian university, semi-retired and retired engineers with industry-based careers were employed on contracts to teach at a level recognising their industry experience, although not competitive with industry. (Example 3)

Model 5: In an Australian university, an engineer took time off from his job to teach into a unit with prepared lesson plans and assessments. This is preferred to models 1 and 2 above only if the engineer is self-employed, and the engineer should be paid at a level that recognises the engineer's industry experience, although the rate will not be competitive with industry rates.

Model 6: A US college recently advertised a one-year contract for an Endowed Visiting Professorship in Science and Technology ("Endowed Visiting Professorship in Science and Technology ", 2013). The expert from industry will teach and 'interact with and mentor students who are interested in careers in computer science. In particular, the appointee is expected to create connections with technology companies'.

F1d. Industry consultation should be structured and transparent

Industry advisory boards should have publicly available membership and terms of reference including the purpose of the board, responsibilities of the chair and members, periods of membership, and diversity among members. Industry consultation should focus on significant issues. In addition to engineering faculty industry advisory boards that discuss current issues, faculties should consider hosting forums to engage industry in longer term planning.

F2. All engineering programs should use industry-based assignments

Academics should use industry-based examples and assignments *extensively* to provide context and give students interactive experience of socio-technical engineering practice using engineering tools.

It can be helpful for one industry-based project to be used in multiple units so that the students understand it well and experience different aspects. For example, students might call for tenders and select a team in one unit and work on project management with the 'winning' tender in another unit.

Current examples of effective practice

Industry-based assignments

Model 1: A mock project was developed and taught within a unit by experienced engineers as unit coordinators (Example 2)

Model 2: A design project with industry as a client was developed and taught within a unit by an academic with industry experience as unit coordinator. A senior engineer gave one two guest lectures a semester. (Example 3)

Model 3: A project using data and presentations from a completed industry project was used in a unit. The project was developed and taught by an academic with industry experience.

F3. All student engineers should have substantial opportunities to work and learn in industry

Engineering faculties should ensure that *all* student engineers have access to substantial opportunities to work and learn in industry, whether through vacation employment, stand-alone internships, or internships as part of a co-op program or diploma of professional practice. (These are identified in the examples below.)

Workplace learning should be resourced, developed and managed with at least as much care as a unit. University staff members led by an academic or engineer should be given responsibility to optimise the availability and quality of opportunities for students. Students should be encouraged to seek student employment in diverse organisations.

Flexible guidelines clarifying responsibilities and process for internships and/or vacation employment must be given to students, staff, and industry-members. As recommended in engineering program accreditation guidelines, students should be supported in reflective practice. Students should have a mentor from the university who might visit the workplace and can be contacted by students during employment.

To help students understand how to make the most of the experience, students who have not yet undertaken workplace learning should engage with returned interns or vacation students. This should be facilitated by an academic or engineer with awareness of engineering practice.

Although an internship or student employment is optimal, students should have a back-up alternative in case no such experience is found. A common alternative to employment is an industry-based project. A second alternative for students can be a collection of experiences exposing the student to practice. The structure for this alternative should be designed to guide the student in making opportunities to gain many of the benefits otherwise offered by an internship or employment. For example, the student might be guided in attending events at Engineers Australia, interviewing engineers in their workplaces, visiting engineering sites, and maintaining a portfolio recording reflections and development during these experiences. This alternative to an internship or vacation employment should be used only as a last resort.

Current examples of practice

Students working and learning in industry

Model 1: Among Australian engineering faculties, the most common model for student engineers to learn while working in industry was 12 weeks of vacation employment. It was usual for this to be required but not contributing to program credit points. The required was usually graded only as satisfied or not, based on the student's report and the industry supervisor's report. Universities stipulated the nature of work that was acceptable. Students found their own employment, universities offered support and many employers visited campus. These could be enhanced as recommended above.

Model 2: At least one research-intensive university (Example 5) and at least three other Australian universities offered students internships of three to twelve months for program credit. Internships were well-structured with negotiated agreements between universities and employers. These would be enhanced by increasing the numbers of students participating.

One Australian university offering internships had 200 students (30-40% of the cohort) on internships in Europe in automotive, aerospace, and manufacturing engineering. After third year, students spent 6 to 12 months on internship contributing to one semester of program credit points. This university reported that students could also do local internships but due to the local culture these were harder to find. Students who did not take an internship were required to complete 12 weeks of vacation employment. This program would be enhanced by increasing student participation.

Another Australian university offering internships had 250 students (approximately 45% of the cohort) on internships, mainly in Australia including a majority in manufacturing and some employed by councils, a casino, and several biomedical companies. After first semester of third year students spent 6 to 12 months on internships contributing to units. (Example 5). This program would also be enhanced by increasing student participation.

Model 3: In four identified Australian universities, student engineers completed two internships. Programs such as this are sometimes called 'co-op programs' and can lead to a combined degree in engineering and engineering practice. These programs took longer than four years. The internships were structured, with units preparing students and helping them reflect on their internships (Example 6). This model addresses the recommendation.

F4. High percentages of students should have opportunities to undertake industry-based final year (capstone) projects

Industry-based final year projects, addressing real research problems faced by industry should be undertaken by many students. The student has an academic and an industry-based supervisor. There should be communication between all three parties (the student and both supervisors) and an agreement regarding responsibilities, confidentiality, intellectual property, and liability. Final year project coordinators should ensure that students and supervisors are aware of the need for an agreement and supervisors should ensure an agreement is in place.

If possible, matching of students and projects should occur well in advance of the students undertaking the projects. This allows time for organisations to offer opportunities for students to visit sites or meet people whose problems the projects will address.

As for internships and vacation employment, engineering faculties should have clearly defined structures for industry-based projects. Academic supervisors of industry projects must scope problems, proposed by industry members, to a suitable size and level. Supervisors should also ensure that assessment criteria are well-defined.

It is important that students are not steered away from aspects of a project that are related to engineering practice although not pure engineering science. Examples are cost analyses related to whether a design can add value for an organisation.

It is sometimes suggested that consulting firms have difficulty offering these projects because they operate on clients' schedules. However this can be overcome by involving consultants and their clients in projects. (Model 1 below)

Current examples of effective practice

Industry-based assignment with consultants and consultants' clients

Model 1: Thirty-two second year students of technology management at the Amsterdam School of Technology worked on 10-week individual projects (Oosterloo, 2005). Each had a university supervisor, a consulting supervisor, and a client supervisor. The client's role was similar to a client's usual role with respect to a consulting firm. It was critical that the academic did not allow the student to scope a project that was too large in an attempt to meet the client's enthusiasm. These projects provided an opportunity for students to develop professional skills for following internships. The model is transferable although it involved second year students. This model included all students.

Model 2: At most Australian universities, academics propose final year projects and students approach academics to work on their projects. Some of these projects are linked to industry-based research undertaken by academics.

Model 3: In a research intensive Australian university, students were encouraged to negotiate final year projects with their vacation employers. The students also had to secure a suitable academic supervisor. This university stipulated that the student should not be paid. This model relies on students' skills at initiating discussions with industry supervisors.

Model 4: Co-operative Education for Enterprise Development (CEED) projects were run at two research intensive Australian universities(http://www.corptech.com.au/home/default.asp; http://www.ceed.uwa.edu.au/). The CEED director negotiated with the industry organisation to provide an industry-based final year project. There was a standard agreement between all three parties: industry, university, and student. In contrast with the above model, the organisation paid the student and the university and the CEED director approached the employer regarding negotiating a final year project. This model is more inclusive than many others.

F5. Emulated work integrated learning is recommended as an example effective industry engagement

Emulated work integrated learning opportunities are recommended as a low-risk way to give students practical experiences in environments that simulate features of engineering workplaces. This does not replace workplace experience.

Current examples of effective practice

Emulated work integrated learning

Model 1: Two virtual processing plants were developed in a collaboration between chemical engineering departments in five Australian universities, BP and Coogee Energy (Cameron et al., 2009). Students could 'walk' through virtual three-dimensional environments representing the two plants. Embedded in the environments were process diagrams, unit processes, unit operations, and system dynamics. Students could learn about the sense of being at the plant, process operations, system dynamics, and risk management. The environments were used by students from first year to the final year of their programs.

Model 2: A miniature plant simulating parts of the Bayer process was built at Murdoch University with support from industry(Hopkinson, 2010). The plant included safety infrastructure such as showers, safety clothes, and safety routines. It was used by students to learn about process control in a simulated industrial environment. Students selected control loops and applied various control algorithms, parameters, and operating points to control pumps and valves.

Model 3: Three universities collaborated with initially 25 industry organisations to establish the 'Learning Factory' which provided hands-on experience for students in an electronics manufacturing facility on campus (Lamancusa, Zayas, Soyster, Morell, & Jorgensen, 2008). Students worked in the factory and then took internships in industry. Their analytical and theoretical learning had an industrial context and they also learnt about aspects of manufacturing engineering such as quality, delivery, and productivity.

Similarly, one Australian university has an advanced manufacturing facility in which students work on project based learning and final year projects supervised by engineers from industry.

Model 4: An Australian university provided an off-campus experience through the university's resources. All third year students went on educational trips on the university's research and teaching vessel. The experience was more industrial than the campus because students had to relate to the professional crew on the vessel.

Model 5: Eight hundred students in various years and disciplines within built environment programs including structural engineering at Amsterdam University of Technology worked on eight design assignments in 80 teams during one week. They camped in empty floors of an office building in a city which was the subject of the design projects. On Monday city leaders and planners met the students to clarify the project. There were 16 relevant guest lectures (two per project) on Tuesday. The students undertook the design on Tuesday, Wednesday and Thursday. Friday included judging and networking with local industry organisations which also provided internships for students.

Model 6: In 2011 the engineering industry liaison manager at an Australian university took engineering and other students to Cambodia to work on 20 humanitarian projects. It was fully funded by grants and industry and some of the projects were ongoing.

F6. Students should be encouraged to take responsibility for seeking opportunities to learn about engineering practice

The benefits of exposure to engineering practice should be promoted to students and they should be encouraged to take responsibility for learning about engineering practice from the beginning of their degrees (if not earlier). Students should take responsibility for their learning and development, including gaining opportunities to learn about engineering practice. Students' reflections should focus on the Stage 1 Competencies and the importance and meaning of these should be well understood by students.

F7. Engineering faculties should support and recognise industry engagement undertaken by student groups

Student societies and student groups working towards competitions should be supported and guided, and integrated into the curriculum. Many students currently gain exposure to practice and opportunities to develop competencies through student societies and involvement in competitions. These provide a platform for helping students realise the importance of industry exposure and being proactive about gaining this from early in the degree. Opportunities taken by students to engage with industry could be considered in their e-portfolios and count towards their exposure to practice, especially when they have been unable to secure engineering student employment. Engineering faculties can support student societies in their industry engagement by providing administrative support such as transport for site visits, promotion of events through faculty newsletters, space for posters, and inexpensive venues and storage space.

Recommendations for Industry

I1. Organisations should provide regular and structured student engineer employment

Engineering employers are encouraged to consider employing vacation students or student interns wherever possible.

Being proactive about managing vacation student recruitment will save time for the organisation and students. Every year many engineering students seek summer vacation employment. Organisations should plan for this by liaising with engineering managers early in the year to identify opportunities for the next year. Organisations should advertise whether vacation employment will be available, the disciplines and locations in which it will be available, and application processes and deadlines. These can be promoted through Engineers Australia, university careers centres, and the organisation's website.

Employers should read the guidelines for vacation employment or internships from universities from which they hire students. If possible, invite your student employee to invite his or her academic mentor or other representative from the university to visit the workplace.

It is critical that at least one engineer has official responsibility to mentor the student, ensure that the student is given support when needed, and ensure the student has responsibilities. It is important that the student interacts with engineers in the workplace, preferably a diverse group of junior and senior engineers.

A senior manager should ensure that the people working with the student are aware of the concept of employing student engineers, the motivation for the organisation employing the student, and their responsibilities to help the student learn. Policies should be in place to ensure that the student is given meaningful tasks and all practical opportunities available. For example, where possible the student should be invited to accompany engineers on any site visits and appropriate events. Networking with other students can provide valuable opportunities for reflection as the students compare their experiences.

Supervision can be eased by preparing a booklet that provides information and questions for the student. The booklet is completed by the student during downtime. The booklet should include: orientation detail; information the student should find out about the organisation, its structure, what it provides, and how it makes a profit; and entries to be completed by the student to encourage reflection on the student's development. Responses can additionally help managers in the organisation to reflect on the organisation's practices and culture.

Supervision is simplified if students are employed every year. Students can continue roles that other students undertook in previous years and students returning for a second period of employment can help students employed for the first time.

The student's welfare must be supported and pay should be appropriate to the employer and the project. Students must have occupational health and safety coverage, and a non-discriminatory environment.

I2. Engineering employers should provide support for their engineers to engage with engineering education

Employers of engineers should encourage and support their staff-members to engage with universities and assist with exposing student engineers to engineering practice. Many of the possible roles that engineers can take to help students learn involve the engineer acting in an emulated engineering team role. For example, graduates can be student mentors. Project engineers might suggest industry-based projects and act as clients. Senior engineers might give guest lectures or serve on industry advisory boards. Other possible formats for engagement are industry weeks on campus, short-term student engagements with industry, and site visits.

Human resource managers should give structure to engineers' engagement with engineering education by designing alignment with organisation needs. Additionally they should structure provisions for engineers to allocate time to engaging with universities, and support organisational commitment to continued engagement.

Current example of effective practice

Unit developed and taught by an engineering organisation with a university coordinator
A design project unit described earlier was run by an engineering organisation. A human resource manager met weekly with the graduate and senior engineers to help design the engagement, help the graduates engage in reflective practice, and align the experience with professional development in the organisation. (Example 2 has further details.)

I3. Engineering employers should provide support for academics to experience industry

Engineering employers should provide opportunities for academics to become aware of their industries. Possibilities to consider are inviting academics to visit sites, network with engineers in an organisation, or providing support to develop teaching materials such as assignment problems, projects, and demonstrations.

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

Establishing a national resource centre for industry engagement in engineering education should be considered, to assist students, universities and industry to identify opportunities and establish relationships.

The resource centre could provide a 'dating' service for employers and students. It could encompass vacation employment, internships, and final year projects. A mechanism so that students can trust the listings as authentic would be necessary. The resource centre staff, possibly using online processes, would collect, publish, and maintain lists of available types of engagement and contact details for universities and engineering employers, and organise regional events to facilitate collaboration. Engineering faculty members, university careers centres, and university development offices should work together such that suitable contacts are clear to engineering employers.

A bank of case studies and exemplars that could be shared between universities, employers and students should be developed. For employers, exemplars would include models of vacation employment programs from organisations of different size and type. For universities, exemplars would include examples of guidelines for internship programs, vacation employment, mentoring programs, site visits, industry-based projects, and engaging student societies. For students, case studies would include examples of how students found vacation employment or internships.

The resource centre staff could also support employers, students, and universities during and following a student's period of employment, by providing opportunities for students and supervisors to reflect at workshops, and using the e-portfolios discussed below. This could be especially helpful for students and supervisors in small organisations.

The centre should support stakeholders in developing networks of people interested in enhancing industry engagement in engineering degrees. Events to establish the networks and online communication tools could be provided to support the networks.

The centre could maintain a record of available teaching resources such as pumps; photographs of sites, failed parts, or safety hazards; examples of specifications and tender documents, which could be shared between universities. These would be provided by industry, and stored in universities, with a record of their location, availability, and an industry contact who can provide further details, maintained as part of the resource centre.

Current example of effective practice

Resource centres to support industry engagement with universities

Model 1: Engineers Australia divisions publish books for students listing details about vacation and graduate employers (Engineers Australia WA Division, 2012). A similar resource for engineering faculties and employers focusing on possible industry engagement with engineering faculties should be considered.

Similarly the Medical Technology Association of Australia established a directory of workplace learning opportunities in the medical technology industry (Shipman & Trimmer, 2008).

Model 2: Engineers Australia divisions hold annual vacation and graduate engineering employment expos. An adaptation for universities and employers should be considered.

B2. Government, professional bodies, and engineering faculties should consider establishing a joint internship scheme

A national engineering internship scheme should be considered by industry bodies, engineering faculties, and the Australian Government. Employers would be able to offer internships in Australia if threshold standards were met. Students would be able to apply for internships with registered universities with the assurance that university requirements will be met. The employer, university, and the student would sign a standard agreement, with variations negotiated between parties if necessary.

Proposed model

National internship scheme

Model 1: Universities Australia proposed a National Internship Scheme (Universities Australia, 2008). It was proposed that the Australian Government should contract out management of the scheme and provide tax incentives to support employers in paying interns.

Model 2: Kelly and Dansie (2012) considered the proposal of a national internship in engineering, reporting a comment that agreed standards would be more appropriate, because diversity between approaches is valuable .

B3. Engineers Australia should consider developing an e-portfolio resource for student engineers

Engineers Australia in consultation with engineering faculties should consider adaptation of Engineers Australia's e-chartered system (https://www.engineersaustralia.org.au/echartered-portal), for student engineers. An e-portfolio for student engineers would be specifically tailored to stage 1 or stage 2 competencies and follow the e-chartered structure so that student engineers could conveniently progress to this as they developed further competencies after graduation.

Current examples of effective practice

Resource to support interns in reflecting on development towards on competency standards

At least two universities aligned student internship report sections with reflection towards development of the stage 2 competencies standards. Several used the stage 1 competencies. At least one Australian university allowed students to use an e-portfolio as evidence for claims of progress towards stage 1 competencies.

B4. Industry bodies should establish and support industry engagement with education

Engineers Australia could consider encouraging engineers to support development of other engineers and students as a competency that engineers should develop and maintain for chartered status.

Industry bodies could recognise industry-university engagement with awards.

Industry bodies should hold some technical events on university campus so that they are convenient for students and academics.

B5. Government incentive should be considered

The Australian Government should consider incentives for employer organisations to engage with engineering education.

Government contracts should be required to build-in education of undergraduate students.

B6. The engineering program accreditation board should review the accreditation guidelines with respect to exposure to engineering practice

The engineering program guidelines are consistent with these guidelines. However, they should be reviewed to investigate the possibility of more strongly encouraging increased industry engagement.

Identified Examples of Effective Practice

1. Faculty brochure for industry identifying potential engagement

http://issuu.com/uqeaitfaculty/docs/engage-with-us-2012

Contact: Jonathan Cosgrove

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Email: j.cosgrove@uq.edu.au | Telephone: +61 7 3365 4302

LinkedIn: http://au.linkedin.com/in/jonathancosgrove1

Features addressing the recommendations
The staff member who developed the brochure was appointed with responsibility to enhance industry relationships.

2. Units developed and taught by companies

At several universities in Australia, engineering organisations take responsibility to develop and teach entire units, with an academic as unit coordinator. The recommended model is for the university to pay the engineers' employer. The university sometimes provides some of the marking.

At one university, a government utility taught a unit on alternate years to make it more feasible for the senior engineers to participate. In the other years the same unit was taught jointly by three consulting companies.

Engineering graduates in the organisation were mentors for students and senior engineers gave lectures. A human resource manager supported the process and reflective practice among the graduates in order to help the graduates develop from the experience. The teaching was well-aligned with the organisation's strategic emphasis on development of people.

In two identified cases, organisations taught a unit each for no financial reimbursement. In each of these, the university had an alumnus championing the relationship, and the organisation employed graduates of the university every year. The organisations benefitted from the opportunity to influence the capabilities of graduates they might employ.

Critical features of the context
A strong relationship between the university and the organisation was critical. Participants in this study frequently noted university alumni within organisations as influential.

Features addressing the recommendations
Students participated in socio-technical activities using engineering tools. Students were exposed to many engineers, assisting identity development. All students participated.

3. Mock project developed and taught by experienced engineers as unit coordinators

Two experienced engineers employed as teaching staff in an Australian university gave units in which students worked individually and in teams on a mock project. The units were developed, taught, and coordinated by the experienced engineers.

The engineers prepared a call for tenders including drawings, contour maps for the site, requirements, and specifications. The students completed quantity take-offs and, as a team, bid for the job. As individuals they completed program schedules using scheduling software. Half way through the job the students were told about events that have happened and they prepared a cost control report for the project manager including recommendations for how to realign the schedule to meet the deadline.

One team member presented the report and the whole team answered questions that a project manager would ask. Students gave and received feedback on how they answered the questions. For example barricading, dishonesty, dodging questions, or avoiding the hard truth were identified as losing trust. Transparency was identified as essential from a project control point of view.

Critical features of the context
The engineers had vast industry experience. They valued strong support from the dean, and felt able to approach him for required resources. Teaching orientation was important. Support from an engineering education researcher helped the engineers to improve assessments to motivate learning and team work. It was critical that the teachers had office space where they could do marking and where students could meet them to ask questions.

Features addressing the recommendations
The students participated in socio-technical activities using engineering tools. They were supported in reflective practice. All students participated.

4. Design project with industry as client

An academic in an Australian university described a design project unit in which an organisation took the role of client and the class project focused on a real project that had not yet started construction but was about to start. This was selected so that data were available but the students were not heavily influenced by a completed design. The students completed a budget, a tender, and a feasibility study. The client presented results of community consultation and other data. External presenters spoke about relevant aspects of the project such as safety and environmental issues. A maximum of about 35 students per project was optimal.

Students organised themselves as a company. They elected positions such as project manager, deputy project manager, quality managers, and team leaders. There were three stages to project and different students were elected into the leadership roles for each stage. Students nominated representatives to meet with the client and they kept the client informed of progress as appropriate. This included five or six student meetings with the client during semester. Students reported against the budget and deadlines. All students presented to the client and the client gave them feedback.

Critical features of the context
The current and previous unit coordinators had extensive industry experience.

Features addressing the recommendations
Students participated in socio-technical activities using engineering tools, with opportunities to build identities, build capabilities, and receive feedback from the client. All students participated.

5. Internship program in a research intensive Australian university

At a research intensive Australian university students could spend up to six months on internship with credit towards their engineering degrees. Students undertook the internship in second semester of third year or first semester of fourth year. The internship did not necessarily add to the duration of a student's engineering program.

The university approved each employer's proposed project, having guided the employer in the nature of suitable projects. Systems for recruiting interns varied across employers. Some recruited through the engineering faculty, leaving the faculty to select the students. Some interviewed after the faculty short-listed. Other employers undertook the whole recruitment process themselves.

A chartered engineer was employed to mentor students while they were on internship and guide them in completing their reports. Students could contact the mentor by email, telephone, or internet as required. The mentor sometimes visited the students and employers during the internships. The report was aligned with stage 2 competencies as required by engineers for chartered status in Australia.

Some organisations involved in the internship program also then engaged with the engineering faculty in other ways. For example, one company provided a field trip for students.

Critical features of the context
The academic leading the internship program had a transformative internship experience as a student and hence was passionate about the value of internships. In this research intensive university, the internship was an alternative to elective units in the program. This was strategic for its approval because it did not displace other engineering units.

Features addressing the recommendations
Students participated in engineering environments with opportunities to build identities and capabilities. The mentor support for writing reports encouraged students to reflect on their

development and learning related to engineering practice.

6. Internship program in an Australian university of technology

At an Australian university of technology, students spent six to twelve months on internship as part of their engineering degrees. Students undertook the internships in second semester of third year or first semester of fourth year. The internship did not necessarily add to the duration of a student's engineering program.

The university had relationships with approximately 300 employers, although not all offered internships every semester. Approximately 250 students at a time were on internships. This included approximately 45% of each cohort. Placements were mainly in Australia including a majority in manufacturing and a casino, councils, and several biomedical companies.

To gain an internship coordinated by the university, students required an average grade of 'credit'. However, students below this grade could secure their own internships. The internship program was managed by a university staff member with human resource and marketing skills. Students applied through the internship scheme online and were then interviewed by the employers, on campus or at the employers' offices. The internship manager helped students prepare resumes and develop interview skills.

Discipline leaders assigned academic supervisors to each student and that supervisor was then responsible for the student while on internship. The supervisor visited the student and on-site supervisor during the internship. Students' reports were assessed as satisfactory or not by the academic and the industry supervisors. The internship program manager also visited sites where possible to maintain relationships.

At this university, students who did not complete an internship were required to enrol in a unit which could be completed through 12 weeks of professional experience in engineering. This could include any one of many types of interaction with industry. Examples are classes given by guest lecturers with industry experience, completing an industry-based project, individual or group site visits, and interviewing professional engineers.

Critical features of the context

The internship program had been operating university-wide for 50 years and therefore it was well-known in industry. Even in this circumstance, the student demand increased every year and finding enough employers was a challenge.

Features addressing the recommendations

Students participated in engineering environments with opportunities to build identities and capabilities. The supervisors and report writing supported reflective practice.

7. Combined degree in engineering and engineering practice at an Australian university of technology

In an Australian university of technology domestic student engineers who were not enrolled in combined degrees with other faculties, completed combined degrees in engineering and engineering practice (BE, Dip Eng Prac), including two internships of at least 22 weeks each. They were required to take the first internship, the junior internship, after three or four semesters. The senior internship had to be completed before the student started his or her final year project. Therefore students studied theory for two years, experienced practice for six months, theory for eighteen months further, practice again, and then theory and application leading to graduation. Every year 600 to 700 students undertook a junior or senior internship.

All internship projects were approved by the university. The junior internship could involve work that might not normally be undertaken by engineers, but was based in an engineering environment and was a valuable learning experience. The second internship was required to be similar to the work of a graduate engineer.

Before their internships each internship student completed a preview unit, and afterwards a review unit. The first preview unit was taught by practice-oriented academics and engineering practitioners, and encompassed personal and professional development and the nature of engineering practice.

In the review units, students were asked to reflect on their development towards the stage 1 competencies stipulated by Engineers Australia. For example, students were required to write significant internship episode reports about their exposure to ethical practice and its implications, and their contributions to it. They were required to write about sustainability, their understanding of it, its practice within the engineering organisation that employed them, their contributions to it, and their influences on it. Similarly, they wrote about team leading, team working, and communication. They were required to provide evidence for their claims in the form of a log book or an e-portfolio. The reports were 30 to 50 pages and worth 50% of the review unit mark. The other 50% was based on students' participation in peer assessment settings.

Students peer reviewed others' reports and advised whether the students should submit their reports or revise the report and accept the penalty for submitting one week later. Many students improved their report so significantly based on feedback that revision was the better option. Review students gave presentations attended by all preview and review students. All students participated in the three to four hours of presentations. Students received grades for their questions.

Many internships grew into final year projects and graduate employment.

Critical features of the context

Key university staff involved in tutoring the preview and review units had substantial industry experience. The tutors were all committed to the program. No tutor was a postgraduate or undergraduate student. Staff with industry experience had been recruited before a research track record became an imperative to joining academia. A program structure involving multiple periods of internship had been well established at this university and well-known among employers since 1965.

Features addressing the recommendations

Students participated in engineering environments with opportunities to build identities and capabilities. The involvement of preview students in review students' presentations supported identity development. The review units supported reflective practice. The peer review opportunities and hearing many student presentations, supported reflective practice and identity development. All students within the program participated.

Project Resource Kit

	Project Resources
Best Practice Guidelines for Effective Industry Engagement in Australian Engineering Degrees	http://arneia.edu.au/resource/43
Summary of Best Practice Guidelines for Engineering Faculties on Effective Industry Engagement in Australian Engineering Degrees	http://www.arneia.edu.au/resource/56
Tool for Reflecting on Effective Industry Engagement in an Engineering Program	In pdf http://www.arneia.edu.au/resource/57
	Online http://uwa.qualtrics.com/SE/?SID=SV_6L5qlmMfwOP45Ip
Benchmark Reflections on Effective Industry Engagement in an Engineering Program	
	Employer Exemplars
Student Engineering Induction Guide	http://www.arneia.edu.au/resource/55
Vacation Student Buddy Training Presentation	http://www.arneia.edu.au/resource/54
	University Exemplars
AMC Employer Handbook	http://www.arneia.edu.au/resource/49
Curtin University Design Project	http://www.arneia.edu.au/resource/52
ECU Engagement Handbook	http://www.arneia.edu.au/resource/51
QUT Work Integrated Learning Unit	http://www.arneia.edu.au/resource/48
QUT Work Integrated Learning Unit background	http://www.arneia.edu.au/exemplar/23
Swinburne IBL Responsibilities	http://www.arneia.edu.au/resource/50
UTS Engineering Practice Program Student Guide	http://www.arneia.edu.au/resource/55
UWA Career Mentor Link Guide	http://www.arneia.edu.au/resource/44

References

Cameron, I., Crosthwaite, C., Shallcross, D., Kavanagh, J., Barton, G., Maynard, N., . . . Hoadley, A. (2009). Development, deployment an deducational assessment of advanced immersive learning environments for process engineering final report. Retrieved from http://www.altcexchange.edu.au/virtual-and-immersive-learning-systems-engineering-and-technology

Cameron, I., & Reidsema, C. (2011, 5-7 December). *Australian engineering academe: a snapshot of demographics and attitudes.* Paper presented at the 22nd Annual Conference of the Australasian Association for Engineering Education, Fremantle, WA.

Endowed Visiting Professorship in Science and Technology (2013). Retrieved from http://mills.interviewexchange.com/jobofferdetails.jsp;jsessionid=DB5397FE81758B507CA4CFB598A8FB0D?JOBID=38029

Engineers Australia. (2012). Australian Engineering Competency Sstandards Stage 2 - Experienced Professional Engineer. Barton, ACT: Institution of Engineers Australia.

Engineers Australia WA Division. (2012). *Engineers Australia WA Division 2012 Undergraduate Vacation Work & Graduate Employment Handbook*. West Perth: Engineers Australia WA Division.

Faulkner, W. (2007). "Nuts and Bolts and People": Gender-Troubled Engineering Identities. *Social Studies of Science, 37*(3), 331-356.

Fletcher, J., K. (1999). *Disappearing acts: gender, power and relational practice at work*. Cambridge, MA: MIT Press.

Godfrey, E., & King, R. (2011). Curriculum specification and support for engineering education: understanding attrition, academic support, revised competencies, pathways and access. Strawberry Hills NSW: Australian Learning & Teaching Council.

Hopkinson, E. (2010). *Murdoch University Pilot Plant Advanced Control Technology Upgrade.* Bachelor of Engineering, Murdoch University.

Kelly, P., & Dansie, B. (2012). S_2P Student to Practice, Hubs and Spokes Project Report.

Lamancusa, J. S., Zayas, J. L., Soyster, A. L., Morell, L., & Jorgensen, J. (2008). The Learning Factory: Industry-Partnered Active Learning. *Journal of Engineering Education, 97*(1), pp.5-11.

Lindsay, E., Munt, R., Rogers, H., Scott, D., & Sullivan, K. (2008). *Engineering students or student engineers?* Paper presented at the Annual Conference of the Australasian Association for Engineering Education, Yeppoon.

Male, S. A. (2010a). *Generic Engineering Competencies Required by Engineers Graduating in Australia.* Doctor of Philosophy digitised, The University of Western Australia, Perth. Retrieved from http://repository.uwa.edu.au/R/?func=dbin-jump-full&object_id=30068&local_base=GEN01-INS01

Male, S. A. (2010b). Generic Engineering Competencies: A Review and Modelling Approach. *Education Research and Perspectives, 37*(1), 25-51.

Oosterloo, G. (2005). Preparing for the workplace, practice and considerations. In E. d. Graaf (Ed.), *Research and Practice of Active Learning in Engineering* (pp. 107-113). Amsterdam: Pallas Publications.

Rychen, D. S., & Salganik, L. H. (2003). *Key Competencies for a Successful Life and a Well-Functioning Society*. Cambridge, MA: Hogrefe & Huber.

Sheppard, S. D., Macatangay, K., Colby, A., & Sullivan, W. M. (2009). Educating Engineers: Designing for the Future Field Book Highlights and Summary. Retrieved from http://www.carnegiefoundation.org/sites/default/files/publications/elibrary_pdf_769.pdf

Shipman, F., & Trimmer, A. (2008). *Driving workplace learning opportunities for secondary and tertiary students in the medical technology industry*. Paper presented at the Australasian Association for Engineering Education Conference, Yeppoon.

The Senate. (2012). The shortage of engineering and related employment skills (Education Employment and Workplace Relations Committee, Trans.). Canberra, ACT: Commonwealth of Australia.

Tilli, S., & Trevelyan, J. P. (2010). Labour Force Outcomes for Engineering Graduates in Australia. *Australasian Journal of Engineering Education, 16*(2), 101-122.

Trevelyan, J. P., & Tilli, S. (2007). Published Research on Engineering Work. *Journal of Professional Issues in Engineering Education and Practice 133*(4), 300-307.

Universities Australia. (2008). A National Internship Scheme. Retrieved from http://www.universitiesaustralia.edu.au/resources/360/87