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Strengthening Teaching and Research: The Use of Industry Links and Case Studies

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Abstract

One approach to develop teaching and research in an engineering school is collaborative partnerships with local industry. The School of Engineering at the University of Tasmania, Australia has adopted this approach systematically and now enjoys a number of productive collaborative research and training partnerships with businesses and industries across the state. The partnerships foster scholarly and scientific cooperation at both the undergraduate and postgraduate levels and also serve to assist the development of graduate attributes by the inclusions of industry case studies in the teaching programs. The paper provides some details of how the School sources its partners and uses the research-teaching nexus to enrich teaching

Introduction

As in most professional degree programs, engineering must address the professional development of its undergraduates, instilling within the students an understanding and appreciation of the profession into which they will graduate. Engineering accreditation bodies such as Engineers Australia (EA) and the Accreditation Board for Engineering and Technology, Inc. (ABET) typically indicate to teaching institutions the desirable attributes that they feel graduates should possess on entering the profession. The teaching institutions then must be able to demonstrate to the accreditors how their engineering programs hlep imbue students with those desired attributes.

Engineering Schools with strong links to industry are able to use the links to assist the development of profession skills in their teaching (and research programs) via incorporation of case studies and state of the art industry practice. The graduate attributes identified by Engineers Australia are listed below and those attributes best able to be developed with the aid of industry links and case studies are shown in *italics.*

Engineers Australia Graduate Attributes

(a) Ability to apply knowledge of basic science and engineering fundamentals
(b) Ability to communicate effectively, not only with engineers but also with the community at large.
(c) In depth technical competence in at least one engineering discipline.
(d) Ability to understand problem identification, formulation and solution
***(e)** Ability to utilise a systems approach to design and operational performance.*
(f) Ability to function effectively as an individual and in multi-disciplinary and multi-cultural teams, with the capacity to be a leader or manager as well as an effective team member.

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(g) Understanding the social, cultural, global and environmental responsibilities of the professional engineer, and the need for sustainable development
(h) Understanding the principles of sustainable design and development
(i) Understanding of the professional and ethical responsibilities and a commitment to them.
(j) Understanding of the need to undertake life long learning, and a capacity to do so.

A case study involving the development of a new process could be used to illustrate to undergraduate students how an existing problem can be identified, a solution formulated via teamwork and the outcomes implemented to provide a responsible and sustainable new process. The fact that students can relate to a local industry partner, who they are familiar with, makes both the problem and the solution relevant to their learning experience. A bonus is that linking of assessment methods with learning outcomes throughout the program, to identify graduate skills allows teaching institutions to market the strengths of their graduates. For example the use of case studies during undergraduate learning could mean that the institution could claim something like "our graduates have an understanding of the real needs of industry".

The School of Engineering at the University of Tasmania has links with a number of industries and some are indicated in Table 1. This paper provides some details of the teaching and research benefits obtained from the link between the mechanical engineering discipline and one of those industries, Comalco (bold in Table 1).

Industry Partner	**Activity**	**Discipline Link**	**Outcomes**
Cadbury	Chocolate and confectionary	Mechatronics Computer Systems	a,b,c c
Aurora	Electricity sales	Power	a,b,c
Hydro	Electricity generation infrastructure	Mechanical Power	a,b,c,d,e,f a,b,d,e
Ecka Granules	Aluminium Powder	Mechanical	b,c
Norske Skog	Paper mill	Environmental (Civil)	b
Councils Public Utilities	Public works	Environmental (Civil) Electronic	a,b,f c,d
Civil Construction Corporation	Civil works	Civil Electrical	a,b,d,f a,b,c
State Government	Civil works	Environmental (Civil)	a,c
Comalco	**Aluminium production**	**Mechanical** Mechatronics Electrical	**a,b,c,d,e** a,b,c a,e
INCAT	Ship builders	Mechanical	c,d,e,f
SKM	Civil consultants	Civil	c,d,f
Furntech	Furniture research	Mechanical	b,f
Zentel	Medical software	Mechatronics	f
Pasminco Co	Smelting	Mechanical	c,f
Rolls Royce	Turbines	Mechanical	a,b,c,d,f

a. General coursework content, b. Case studies within coursework
c. Honours projects (unfunded) d. Honours projects (funded)
e. Research Higher Degree projects (unfunded)
f. Research funds (including scholarships and consultancies)

Table 1. Links between Industry and the School

Identifying and Capturing Industry Partners

Industry is predominantly captured in two main ways, by proactive action from the individual/School, or via casual inquiries by industry. A casual inquiry usually means that someone in industry has a problem that they feel interesting, complex and solvable by academia in a very "cost-effective" manner. For this paper the authors will limit discussion to the proactive approach.

In a hypothetical case where a new academic joins the School and has few links to local industry, it falls to the academic's mentor and/or School management to assist the new academic to establish a niche in the local market. This situation will typically require direct action by the School to accelerate development of the new academic's research, teaching and professional profile. One system that has been found to work well within the School is outlined in point form below.

- Informal talks are held between the HOS, other active senior staff and the keen new academic, to explore/confirm practical (applied) research interests and expertise.
- Identification of possible industries to target for collaboration then takes place, ensuring that conflict with existing partnerships is avoided.
- The HOS or other senior staff then informally approach senior management within the selected target partner to ascertain the level of interest in collaboration. At this time the attributes of the new academic are extolled.
- Subsequent to the success of the high level meeting, technical level meetings are scheduled. The HOS may attend these initially to indicate the strong support that the School lends to the new academic and his/her projects.
- A range of outcomes should flow from the technical level discussions, as those involved have some confidence that their projects will gain some level of support from their managers.

Quite often the first collaboration will be via honours projects for final year undergraduate students, as this approach will cost the client very little and also allows them to gain some confidence in dealing with academics and the School. The partnership progression is then (hopefully) contract research followed by a collaborative application for the all-important competitive federal grant scheme.

Creating a Teaching-Research Nexus

Once an academic has established a good link with industry the more interesting phase is reached where development and nurturing of the nexus must be take place to ensure that benefits flow to both all. The School is obviously a very interested stakeholder in addition to the individual academic(s)

Much has been written about the nexus between teaching and research in universities [1] and how both contribute towards scholarship. Simplistically academics generate or create knowledge and then transfer it to students via the teaching process. Boyer [2] frames scholarship into the four areas of scholarship of discovery, scholarship of integration, scholarship of application and scholarship of teaching. In this paper however, the authors have taken the more common model that scholarship encompasses academic excellence in both teaching and research. Discovery and application is then bundled into research, while integration and teaching is bundled into teaching.

Pragmatically, academics in Australia who are entrants in the promotion/tenure stakes find it wise to have a portfolio that can show outstanding performance in both teaching and research. It quickly becomes very apparent to young academics that no resource should be wasted and that any relevant research outcome should be used as a teaching resource where and when possible. They will also realise also that undergraduates can contribute to research. This fits well with Brew's [1] comments that, *"the implications of bringing research and teaching together within academic communities of practice mean that students would be treated as the adult people that they are, with something valuable to contribute as well as to learn"*.

A schematic representation of how research and teaching could be linked is shown in Figure 1. Project and honours students have special significance, as that group often forms the crucial link between the undergraduate and postgraduate student bodies. For the clarification of the global reader, Australian undergraduate engineering degrees are of 4 years duration, and the main body of entrants come directly from senior secondary school. These students are typically 17 to 19 years old at that time. Graduates with honours degrees may be permitted to undertake a research masters degree (typically 2 years duration) or a doctorate (typically 3-4 years duration). A very good student could plausibly complete their undergraduate degree and research doctorate by the age of 25 to 26.

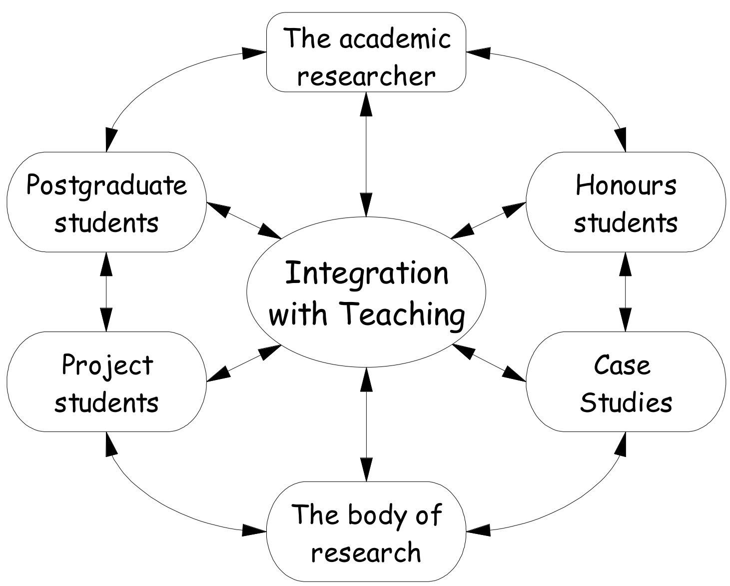

Figure 1. A Research-Teaching Nexus

Clustering and sequencing honours projects around a common research theme accelerates research development, especially in the absence of postgraduate students. Sequencing projects is to run a series of very similar projects over a number of years, each year gradually building on the foundation of the previous. Sequencing typically only lasts for around three years after which the work tends to become outdated and stale.

Clustering projects involves more than one group of students working on different aspects of the same project. This can create a synergy among groups, as all groups can access the combined body of work, while still restricting their reports to their own selective subset of the total project [3]. This approach is useful with industry partners who can provide an ongoing source of undergraduate projects that may lead into larger scale research, strengthening the research-teaching nexus. This process was successful with the industry partner referenced in this paper (Comalco) with several honours and research projects being completed within the School with the first author during the life of the partnership.

A Case Study

The industry selected to illustrate the transfer of research outcomes into teaching is Comalco, which is an aluminium producer with three major smelters based in Queensland, Tasmania and Invercargill (New Zealand). Aluminium's broad range of excellent physical properties makes it particularly useful to mechanical engineers and its manufacturing process is well suited to a case study in that discipline.

The relationship with Comalco was initially developed under an applied research link. The overarching research project involved the development of new process and performance models based on the rapidly developing field of neural networks and artificial intelligence. It was envisaged that these would replace dated empirical models that could only deal with a small number of input parameters. The academic's (first author) intent was that the research project and its outcomes could be re-packaged as case studies in the mechanical engineering discipline teaching program. The research project devolved into the following sub-programs.

- Temperature prediction techniques
- Anode effect in cells.
- Monitoring of cell conditions

Temperature Effects
Electrolyte, or bath, temperature is an important cell parameter in aluminium production, as it is a significant indicator of how stable and efficiently a reduction cell is operating. Remote sensors, such as optical pyrometers and measurements of the intensity of infrared radiation, are not practical or accurate enough[4] and mineral insulated metal sheathed thermocouples, last only for a very short period[5]. It was considered that a temperature prediction technique, such as a neural network, would eliminate the problems associated with manual temperature measurements. This became one of the research projects and eventually part of the case study for KNE353 Manufacturing, Maintenance and Quality.

Anode Effects
A significant and potentially catastrophic process parameter in aluminium smelting is the 'anode effect'. The anode effect occurs when the electrolyte becomes depleted in alumina. The first sign of an anode effect is a gradual and potential rise in voltage. This will result in increased energy consumption, reduced metal production, overheating of the cell and reduced cell life[6]. This became the second research project and was used as a case study in KNE453 Advanced Manufacturing and part of the case study for KNE353 Manufacturing, Maintenance and Quality.

Cathode Delamination, Potholes and Tapholes
One of the main factors influencing the cost of metal production and subsequently, the profitability of an aluminium electrolysis cell, is the life of the cell lining[7]. When a cell failure occurs it is usually due to cathode delamination, longitudinal cracking or pothole/taphole formation. The use of process modelling to minimise these failures became the third project,

which was incorporated into the undergraduate program via the case study in KNE353 Manufacturing, Maintenance and Quality.

Outcomes of the Partnership

Research outcomes.

The current practice in Australian smelting industry involving heuristic methods had no reliable means of predicting such catastrophic failures. Although the physics of the problem is well established, the precise degree of influence of process parameters contributing to various failure modes in a reduction cell was largely unknown. The overall collaborative project developed intelligent tools for reliable estimation of cell failure times. The research also provided multi-disciplinary, project based training for research students, who would enter the industry.

Equally important (to the School) was the dissemination of the research outcomes via publications in international conferences and journals over the 3 years of active liaison[8-14] and the transfer of the research into the teaching program via development of case studies. In general terms the research outcomes could be described as follows.

- Building alliances between Australian researchers and their industry partners to explore and develop the commercial potential that may be generated from collaboration;
- Acquiring new knowledge and skills in specialised areas and an understanding of the market and operating environment for aluminium smelter products and services;
- Enhancing aluminium production and research as a result of lower production costs and dissemination of the research outcome to other Comalco smelters.
- Dissemination of knowledge by publishing the research outcomes in the international conferences and journals. There have been three research higher degree completions as a result of this collaboration[15,16,17].

Teaching and learning outcomes

One major outcome of the collaboration with Comalco was the development of a number of honours projects related to the research outcomes. In the last five years there have been projects related to product flow, cathode designs and cell maintenance[18,19,20]. This helped firm the research-teaching nexus in the area, as while honours sits in the final semester of the undergraduate degree, it also forms the basis for the development of research skills and the generation of further interest in pursuing research studies.

Engineering as a profession requires constant addressing of the curriculum to incorporate state of the art industry best practice. Dated teaching material does not assist graduates to develop the skills to cope with the immediate manufacturing needs in a dynamic industry environment. Practical examples and industry case studies taught should thus be continuously revised to keep abreast of industry developments. This is best supported by partnerships with industry and the School's collaboration with Comalco has helped to maintain scholarship in teaching by incorporating recent developments in the aluminium production industry into the teaching program.

Specifically the research outcomes have been incorporated into 3rd Year (KNE353 Manufacturing, Maintenance and Quality) and 4th Year (KNE453 Advanced Manufacturing) units to assist the teaching and learning activity of students in the mechanical engineering discipline. The School uses a graduate attribute mapping process to link learning outcomes with Engineering Australia graduate attributes and matrices for KNE353 is provided in Table 2 and the matrix for KNE453 is provided in Table 3.

In KNE353 all three research outcomes are subsumed into a case study (aluminium production). This focuses on product flow and process planning of aluminium manufacturing, which reinforces graduate attributes "h" and "j". The students do not use the direct research outcomes as specific case studies as they do not possess the required skills at this stage of their learning. Instead the research outcomes are used to demonstrate to the students how applied research (carried out by the School) can be used in industry to enhance production processes in a local industry.

KNE353 **Manufacturing, Maintenance and Quality**	**Graduate Attributes**				
	a) Ability to apply knowledge of basic science and engineering fundamentals	d) Ability to undertake problem identification, formulation and solution	f) Ability to function effectively as an individual and in multi-disciplinary and multi-cultural teams, with the capacity to be a leader or manager as well as an effective team member	h) Understanding of the principles of sustainable design and development	j) Expectation of the need to undertake lifelong learning, and the capacity to do so
Estimated % Split	**30**	**20**	**20**	**20**	**10**
Statistical quality control - quality accreditation.	Assignment	Assignment	Examination	case studies	Assignment
Theory of metal cutting and practical machining processes. Modelling of three dimensional tool/workpiece interference for performance prediction.	Examination	Examination	Laboratory	Examination	Assignment
Introduction to group technology, flexible manufacturing systems and just-in-time manufacturing.	Examination	Assignment	Laboratory	Case studies (Aluminium production)	Case studies (Aluminium production)
Product development and design appraisal for formula SAE race car components.	Examination	Examination	Laboratory	Examination	Assignment
Presentation:	Lectures, tutorials, laboratories				
Assessment:	Assignment, case studies, examination				

Table 2. Graduate Attribute Development in KNE353

In KNE453 the Anode Effect research outcomes are used as a specific case study. Since the research outcomes have been implemented by Comalco, data from the on-line monitoring of reduction cells is available. The company commissioned the production of a video, which shows the overall production process and highlights the new system for evaluating anode condition. An on-line digital display, which shows "hours to failure" appears in the video as part of the on-line condition monitoring. The students use first principles and manufacturing models to evaluate the manufacturing process off-line and compare their calculations with the on-line monitoring data. The case study reinforces the graduate attributes of "h" and "j".

Similarly the case study from Ecka Granules (see Tables 1 and 3), which covers the manufacture of aluminium powder from molten aluminium, caters specifically for graduate attribute "h", in KNE453. The group based case study involving the development of a Formula SAE racecar (Society of Automotive Engineers) became an excellent example of independent learning via multi-disciplinary and multicultural teams, addressing graduate attribute "f" in KNE453 (Table 3).

KNE453 **Advanced Manufacturing**	a) Ability to apply knowledge of basic science and engineering fundamentals	d) Ability to undertake problem identification, formulation and solution	f) Ability to function effectively as an individual and in multi-disciplinary and multi-cultural teams, with the capacity to be a leader or manager as well as an effective team member	h) Understanding of the principles of sustainable design and development	j) Expectation of the need to undertake lifelong learning, and the capacity to do so
Estimated % Split	**30**	**20**	**20**	**20**	**10**
Ability to appraise performance predictive models for advanced conventional and unconventional machining operations.	Assignment	Assignment	Examination	case studies	Assignment
Design and evaluate operations research tools for industry cases for automation problems.	Examination	Examination	Laboratory	Examination	Assignment
Ability to plan, design and construct economics of manufacture models. Develop break-even analysis for machine tool selection, process comparison and appraisal.	Examination	Assignment	Laboratory	Case studies (Anode effect)	Case studies (Anode effect)
Product development and design appraisal for Formula SAE race car components.	Assignment	Assignment	Case studies (SAE Formulae)	Case studies (Ecka Granules)	Assignment
To gain a broader knowledge of modern manufacturing techniques such as product development, operations research and operations planning.	Examination	Examination	Laboratory	Examination	Assignment
Presentation:	Lectures, tutorials, laboratories				
Assessment:	Assignment, case studies, examination				

Table 3. Graduate Attribute Development in KNE453

Experience in the School has shown that some graduate attributes (for example g,h,i,j) are more difficult to incorporate into teaching programs than others (for example a,c,e). In 2003 the School undertook a mapping exercise of all its teaching (> 60 units) regarding demonstration of how graduate attributes were imbued into students during their learning experience. This exercise was partly in response to an Engineers Australia accreditation visit that took place in October 2003. The summary of the mapping exercise is provided in Table 3. The information in Tables 2 and 3 for KNE353 and KNE453 would form a subset of the mechanical engineering discipline shown in Table 4 (2 of 32 units).

The information in Table 4 provides overall details of the mapping exercise carried out for all units in all of the School's engineering disciplines. Case studies appear to be a useful resource to help develop some of the more "difficult" student graduate attributes such as *Understanding the principles of sustainable design and development* (see attribute "h" in Table 4).

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EA Generic Graduate Attributes and Summary									
Discipline	a	b	c	d	e	f	g	h	i
Civil	30%	7%	17%	16%	4%	10%	3%	4%	2%
Comp. Systems	34%	6%	12%	19%	9%	12%	3%	3%	2%
Elec. & Comp.	33%	5%	12%	19%	9%	13%	3%	2%	2%
Elec. Power	32%	5%	13%	18%	9%	14%	3%	2%	2%
Mechanical	32%	5%	13%	18%	7%	10%	3%	5%	2%
Mechatronic	31%	6%	13%	19%	9%	12%	2%	3%	2%
Average	**32%**	**6%**	**13%**	**18%**	**8%**	**12%**	**3%**	**3%**	**2%**

Table 4. Mapping the Degree Programs for Graduate Attributes

Conclusions

The paper illustrated how industry links can be used as a vehicle to develop the teaching and research portfolio of an engineering school. Research outcomes can strengthen both teaching and learning activities by incorporation in the teaching program as case studies. For this transfer of knowledge to occur a good teaching-research nexus must exist or be developed by the academic and School.

The collaboration was able to address the identified specific problems related to both production process and cell maintenance in the manufacture of aluminium and the reliable quantitative predictive models for cell performance and failure criteria appear to have greatly benefited the industry partner. The multi-disciplinary nature of the collaboration also assisted in training high quality research higher degree students and in the publication of international refereed publications.

The contribution of the case studies to teaching and learning within the School can be tracked through the graduate matrices that map the delivery of learning outcomes. It was shown how research could lead to a number of successful design and honours projects for final year students, reinforcing the teaching-research nexus and strengthening the ties between the School and its industry partners.

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Biographical Information

Associate Professor Vishy Karri is an accomplished and enthusiastic teacher and in 2001 won the National Teaching award for the sciences and engineering. Vishy has an extensive publication record in the areas of alternative energy systems integration and the application of neural networks and artificial intelligence to manufacturing processes. He teaches both first and final year engineering students with great vigour.

Professor Frank Bullen has lectured and practiced in 5 countries and has an extensive publication record with over 100 articles in international and national technical journals, conferences, symposiums and workshops. Frank’s research involves innovative teaching and learning approaches and the technical areas of pavement materials and design, soil stabilisation and characterisation of fibre reinforced concrete.