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PREPARING ENGINEERS & SCIENTISTS FOR THE 21ST CENTURY: A CASE FOR IMBEDDING AN INHERENT AWARENESS OF INTELLECTUAL PROPERTY IN UNDERGRADUATE ENGINEERING & SCIENCE CURRICULA

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I Introduction

This paper has its origins in an invitation extended to one of the authors to present a guest lecture to final stage undergraduate engineering students at the University of Technology, Sydney (UTS). The lecturer's brief was to present an overview of Intellectual Property (IP) as a component of an enterprise module of a capstone subject. The lecture explored the relevance to engineers of patents, trademarks, copyright and confidential information. The initial phase of the lecture was uneventful. The students' level of interest was commensurate with the lecturer's expectations of final year students generally. The students engaged with the material and asked intelligent questions. However, towards the end of the lecture, the concept of confidentiality, and the consequences of inadvertent release of confidential information were introduced. These consequences were illustrated by a survey of US corporations conducted by PricewaterhouseCoopers and the American Chamber of Commerce in 2002[1] showing that 138 of the corporations surveyed suffered losses of between US$53 and US$59 billion through incidents in which proprietary information was disclosed. The magnitude of these loss statistics was a catalyst that transformed the lecture from an interesting information session about IP, into something that was perceived by students to be extremely relevant to their immediate futures. The pedagogical truism that personal involvement enhances engagement transformed the lecture. One student's question illustrates the mood of the lecture: *Why haven't we been made aware of something as important as this much earlier in our course?*

II The Importance of Intellectual Property Awareness for Engineers and Scientists

Laney[2] used the expression 'inherent' to describe the relationship between IP and the professions of science and engineering. He saw the synergy between scientists and engineers as: 'Scientists discover new ideas, materials, and processes that engineers

[1] Puay Tang and Jordi Molas-Gallart, Working Paper 130 - Science and Technology Policy Research Unit of the University of Sussex <www.sussex.ac.uk/spru/1-6-1-2-1-27.html> at 28 February 2007.
[2] Orin Laney, Intellectual Property and the Rights of Creative Employees, *Professor Laney's personal web page*, (1999) <http://www.orinlaney.com/ipguideweb.html> at 28 February 2007.

draw upon for their work.' He asserted that as professional innovators, engineers are by definition also 'prolific creators of intellectual property'. He argued that IP should be at the forefront of an engineer's mind because 'every schematic produced, each piece of software code, every drawing, diagram, and prototype has intellectual property rights attached upon creation'. Grimson[3] suggests that 'traditionally the emphasis in engineering education has been on the scientific side, with students given a thorough grounding in the basic scientific and mathematical principles underpinning their discipline'. He argues that 'a re-engineering the curriculum for the 21st century' is needed to provide the demands for new skills and other knowledge domains.

In his seminal IP guide for scientists, *Basic Workbook In Intellectual Property Management,* Professor Erbisch details a personal experience that illustrates how important IP is to scientists:

> During my second year as Director I received a publication on successful inventions. I looked through it and there was a description of a successfully licensed invention, which to my surprise was identical to a successful research project a graduate student and I had conducted several years previously. Our work had been completed before the work in the article had been started! They had patented their results, we hadn't. We didn't know we had an invention! No one at the university knew what we had done was an invention. We had missed an opportunity to patent. That was very disappointing. However, it gets even worse. The patented research had been licensed and in its first year on the market sold more than U.S. $19 million worth of the patented material! Now I was really interested in knowing all about intellectual properties. I also wanted to make sure that not being able to recognise an invention did not happen to anyone else at the university. [4]

IP awareness is analogous to other non-core skills or knowledge for engineers and scientists, such as: management skills, communications skills, teaming & interpersonal skills and ethical behaviour awareness. In recognition of this

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[3] John Grimson 'Re-engineering the curriculum for the 21st century' 2002 27(1) *European Journal of Engineering Education* 31.
[4] Frederic Erbisch, *ABSP Basic Workbook in Intellectual Property Management* (2004) 3.

fundamental status, IP awareness must be introduced into undergraduate engineering and science curricula. The question is: can a non-core element like IP awareness be introduced into undergraduate engineering and science curricula seamlessly, and without sacrificing any existing core curriculum elements? This paper argues that it can be, by applying a pedagogy of imbedding an inherent awareness of IP in undergraduate engineering and science curricula, rather than creating stand-alone IP subjects or IP modules.

III IMBEDDING: A PEDAGOGIC STRATEGY FOR INTEGRATING NON-CORE ELEMENTS INTO CURRICULA

The authors believe that a pedagogic strategy of 'imbedding' is best suited to achieve the objective of integrating non-core elements like IP into undergraduate engineering and science curricula. But, before examining the strategy of imbedding non-core elements in curricula, it is important to clarify the notion of 'imbedding' as it used in this article, and distinguish it from the more commonly used notion of 'integration'.

Froyd and Ohland describe a range of curricula integration strategies used by the engineering education community, ranging from integrating new technical coverage into the engineering curriculum, to integrating a core basic like biology throughout chemical, and environmental engineering curricula, rather than as a single dedicated subject. The characterisation of integration used by Froyd and Ohland that best describes the curricula strategy to which the authors ascribe the term 'imbedding' is 'integrating a thread of a particular non-technical subject into an otherwise unchanged engineering course or curriculum, including business, communication, ethics, culture, and sustainability'.[5]

Adding additional non-core material to what Fromm[6] describes as 'an already overburdened' engineering and science curricula will be a challenge. However, it is a

[5] Jeffrey Froyd and Matthew Ohland, 'Integrated Engineering Curricula' (2005) 94 *Journal of Engineering Education* 147.
[6] Eric Fromm, 'The Changing Engineering Educational Paradigm' (2003) 92 *Journal of Engineering Education* 113.

challenge that has been faced, with considerable success, by engineering and science curriculum designers for some time now. In the late 1980's, bodies external to universities like the American Association of Engineering Education, Accreditation Board for Engineering and Technology, and the American Chemical Society called for undergraduate programs to place more emphasis on non-technical skills and knowledge. Einstein[7] documents a long-running program, funded by the National Science Foundation (NSF), which was designed to encourage substantial curricula changes. In the period 1987-1995, NSF funded eight Engineering Education Coalitions (EEC), who all reported examples of successfully introducing many non-core elements into undergraduate curricula. The objective of the EEC program was to overcome perceived shortcomings in engineering education, including improving engineers' communication skills and their awareness of ethical behaviour.

Evaluation of the EEC programs identified three common pedagogical strategies used to introduce non-core elements into undergraduate curricula:

1. 'stand-alone' approach, where a specific non-core element is created and delivered (often by a 'non-core' academic) as a discrete subject in a course;
2. 'modular' approach, where a discrete non-core element module (often developed by a non-core academic) is introduced into a core subject; and
3. 'imbedded' approach, where non-core elements are imbedded into one or more of the course subjects. An imbedded approach can also be taken across the whole curriculum.

Of these strategies, the EEC experiences suggest that the stand-alone approach and the modular approach present difficulties to curriculum designers. The principal difficulty that arises with the stand-alone approach is time constraints 'simply do not permit the development of individual sets of independent courses' in already over-burdened curricula. Drake et al. compared and assessed the results of delivery of engineering ethics at Georgia Institute of Technology by both stand-alone and

[7] Herbet Einstein, 'Engineering Change at MIT' (2002) 72 *Journal of Civil Engineering* 62.

modular approaches. The objective of this research was to determine which of the three pedagogical approaches produced maximum changes in moral awareness skills of engineering students. The research revealed that a stand-alone full course did not make a significant increase in moral reasoning (when compared to a control group). They concluded that some sort of comprehensive approach was needed to achieve the objective of increasing engineering students' moral reasoning. The research found that a limited module is not sufficient for improving moral reasoning skills of engineering students.[8]

Knight and Yorke[9] recommend caution when adopting either stand-alone or modular approaches. In particular, they warn that the use of 'detached one-off modules' carries the risk of such modules being 'treated as marginal'. They did however recognise that of the two approaches, the modular approach has the benefit that 'it is much easier to tailor to the student's discipline, an attribute that many argue is essential'. The literature suggests that of the three pedagogical strategies ['stand-alone', 'modular' and 'imbedded'], it is the imbedded approach that offers the most effective means of adding an additional non-core element like IP awareness to engineering and science curricula.

IV A PEDAGOGY FOR INTRODUCING IP AWARENESS INTO ENGINEERING AND SCIENCE CURRICULA

To date endeavours of engineering and science curricula designers to include IP awareness teaching in undergraduate engineering and science courses are at a nascent stage.[10] Also, it appears that:

- IP awareness elements tend to be limited to capstone enterprise or similar subjects, and

[8] Matthew Drake et al, 'Engineering Ethical Curricula: Assessment and Comparison of Two Approaches' (2005) 94 *Journal of Engineering Education* 223.
[9] Peter Knight and Michael Yorke, 'Employability and Good Learning in Higher Education' (2003) 8 *Teaching in Higher Education* 5.
[10] Ruth Soetendorp et al, 'Engineering Enterprise through Intellectual Property Education – pedagogic approaches' (2005) 2 *WSEAS Transaction in Advance in Engineering Education* 1790.

- Faculties of engineering and science tend to turn to specialist IP legal academics to deliver or develop IP modules for those capstone subjects.[11]

Given this nascent stage of development, it may be timely to consider an alternative approach to creating an inherent awareness of IP in engineering and science curricula. A different approach to the one described above for creating general awareness of law in non-lawyers may be needed for engineering and science students; at least in the early stages of their undergraduate studies. It may be more efficacious to present IP to engineering and science students through engineering or science lenses, rather than through a legal lens.

To engender serious engagement of engineering or science students with IP concepts, the pedagogic design must accommodate the common sense theory of why students do or do not learn, 'the expectancy-value theory of motivation' which says 'that if anyone is to engage an activity, he or she needs to value the outcome and expect success in achieving it'.[12] Biggs asserts that if either 'value' or 'expectancy' are not present, 'then no motivated activity occurs'. Biggs also stresses that the expectancy – value theory is particularly relevant 'in the early stages of learning, before interest has developed to carry continued engagement along with it'.

V Pedagogy Models for Teaching 'IP Awareness across the Curriculum'

In this article we provide examples from universities in the USA, United Kingdom and Australia to offer useful primers to assist curriculum designers wishing to develop models for IP awareness pedagogies. This article briefly examines some of the literature relating to the analogous embedding pedagogies of:

- Imbedding 'writing across the curriculum' in engineering courses;
- Imbedding ethics awareness in engineering curricula, and

[11] Robert McLaughlan et al, 'Engineering Enterprise through IP Education: What is needed?' (Paper presented at the Proceedings of 4th ASEE/AeaE Global Colloquium on Engineering Education, Sydney, 26-29 September 2005).
[12] John Biggs, *Teaching for Quality Learning at University* (1999).

- Imbedding ethical awareness in undergraduate medicine and law curricula.

A *Writing across the Curriculum*

The most common expression used to describe the contemporary pedagogical strategy of imbedding improved writing skills in engineering and science curricula is 'writing across the curriculum'. As a pedagogy, writing across the curriculum is a tried and tested model for introducing a non-core element into undergraduate engineering programs. It is proposed as a model for introducing IP awareness into engineering and science curricula. This article argues that an imbedding strategy similar to writing across the curriculum would best suit the objective of creating an inherent IP awareness – hence we have coined a title to the pedagogy described in this article – 'IP Awareness Across the Curriculum'.

Recent writing across the curriculum experiences in the engineering and science disciplines have seen curricula designers turn to a strategy of imbedding non-core elements into whole courses, rather than creating a single 'writing' subject as part of the curriculum. The surveys of twenty-one institutions cited by Ford and Riley[13] illustrate the prevalence of imbedding as the preferred pedagogical approach to writing across the curriculum.

B *Imbedding Ethical Awareness in Engineering Curricula*

Until the late 1990's, formal ethics was a minimal component of Australian engineering curricula. As that situation changed, curriculum designers adopted a teaching approach that focused mainly on one or two subjects that explicitly raised and dealt with ethics issues. Australian universities adopted a more or less compartmentalised approach to engineering ethics education that provided specific locations for ethics discussion.

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[13] Julie Ford and Linda Riley, 'Integrating Communication and Engineering Education: A Look at Curricula, Courses, and Support Systems' (2003) 92 *Journal of Engineering Education* 325.

Johnston[14] documented an example where ethics teaching was imbedded across the whole engineering curriculum. In 1998-99, UTS Faculty of Engineering adopted an alternative, integrated, approach to teaching ethics awareness in its five-year undergraduate programme. Johnston et al. describe the UTS approach as ‘not to separate out the ethics issues, but deliberately to interleave them through the programme’. This approach focused students on ‘the discourse of engineering practice, not just engineering science, whilst illustrating that ethical issues are an essential part of the context for all aspects of that practice’.[15]

C *Imbedding Non-Core Elements in Medicine Curricula*

The *Oxford Practice Skills Project* (OPSP) was a milestone example of the successful use of imbedding as a pedagogical approach to embed non-core skills and knowledge across a whole curriculum. The OPSP experience has added relevance to this article in it used imbedding not only for ethics awareness, but also for introducing basic legal knowledge and communication skills into the curriculum for clinical medical students. ‘These three elements of practice are approached in an integrated teaching programme which aims to address everyday clinical practice.’[16] Imbedding was found to be of particular utility to create an inherent and holistic awareness of each of the skills.

In 1993 the University of Glasgow, substantially changed its approach to teaching ethics in their medicine curriculum. The change involved moving from teaching ethics as a final year subject, to imbedding ethics awareness over three years of undergraduate teaching. Goldie[17] reports that the specific, and successful, format adopted was: 30 hours (mainly small group teaching) in year 1, followed by 14 hours (mainly lecture-type teaching) in years two and three. They concluded that a

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[14] Stephen Johnston, Helen McGregor and Elizabeth Taylor, ‘Practice-focused Ethics in Australian Engineering Education’ (2002) 25 *European Journal of Engineering Education* 4.

[15] Ibid.

[16] Trevor Hope and Keith Fulford, ‘The Oxford Practice Skills Project: teaching ethics, law and communication skills to clinical medical students’ (1994) 20 *Journal of Medical Ethics* 229**.**

[17] John Goldie et al, ‘The impact of three years' ethics teaching, in an integrated medical curriculum, on students' proposed behaviour on meeting ethical dilemmas’ (2002) 36 *Journal of Medical Education* 489.

measurable improvement in learning outcomes had been achieved. Walker[18] reported similar results from their University of Chicago experience of imbedding ethics across the entire medicine curriculum.

D *Imbedding Ethics Awareness in Law Curricula*

Imbedding is a pedagogical approach also widely used to introduce ethical awareness into law curricula. This was done to address concerns expressed by the legal profession similar to those expressed by the medical profession, that recent graduates lacked ethical awareness and a grounding in ethical behaviour.

Since the mid-1970s, the American Bar Association has required accredited law schools to provide instruction in professional responsibility. Awareness of ethical responsibilities is a substantial part of professional responsibility of lawyers. Luban[19] documented the American legal profession's concerns. The concerns held by the Australian profession over the lack of ethical awareness in Australian law graduates is documented in the Australian Universities Teaching Committee's *The Promotion of Effective Teaching and Learning of Legal Ethics and Professional Responsibility in Australian Law Schools*.[20] This concern is international. The mandatory inclusion of ethics training is a requirement of most of the world's legal accreditation bodies.

VI CONCLUSION

The mindset of modern corporations is changing rapidly. There is a realisation that whereas competitive advantages were once based primarily on low labour cost, access to raw materials, and abundant capital, now IP is perceived as defining the core competencies of the company and, in particular, a company's ability to innovate rapidly and successfully. Commercial enterprises are moving from manufacturing to knowledge-based products. Companies that once defined themselves as

[18] Robert Walker et al, 'Development of a teaching program in clinical medical ethics at the University of Chicago' (1989) 64 *Academic Medicine* 723.
[19] David Luban and Michael 'Good Judgment: Ethics Teaching in Dark Times' (1995) 9 *Georgetown Journal of Legal Ethics* 31.
[20] Marlene Le Brun, *The Promotion of Effective Teaching and Learning of Legal Ethics and Professional Responsibility in Australian Law Schools* (2001).

'manufacturing' now define themselves as 'research and design'. As a consequence of this, 'many companies no longer have the bulk of their assets locked-up in plant and machinery, but increasingly in their IPR'.[21] Therefore, engineering and science curriculum designers must recognise that it is essential for 21st Century graduates to be properly prepared to take their place in the knowledge economy.

In the 'knowledge economy' it is imperative that engineers and scientists have an acute awareness of the role of IP in their professions. IP permeates virtually every facet of the practice of engineering and science. In respect of undergraduate engineering and science curricula, creating an inherent awareness of IP is as important as creating an awareness of essentials such as written and oral communication skills, occupational health & safety awareness and ethical behaviour.

Undergraduate engineering and science students should be encouraged to develop an inherent awareness of IP early in their courses. Given that introducing IP as a non-core stand-alone subject into already overcrowded curricula is problematic; it is recommended that IP awareness should be imbedded in undergraduate engineering and science curricula. In respect of developing engineering and science pedagogies to achieve this objective, curriculum designers can draw on the pedagogy of embedding ethical awareness in undergraduate curricula of medicine and law.

The success of the pervasive method to achieve imbedding of an inherent awareness of ethics in law graduates invites a direct analogy for the use of imbedding pedagogies in undergraduate engineering and science curricula to create an inherent awareness of IP in graduates.

[21], European Commission Enterprise Directorate-General, *The European Trend Chart on Innovation - Thematic Report: Innovation and IPR* (2001) <http://trendchart.cordis.lu/Reports/Documents/Innovation_and_IPR_September_2001.pdf> at 28 February 2007.