Innovation in Cross-Faculty Education:
Engineering and Science

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Abstract

"Introduction to Innovation" is a unique cross-faculty subject that has just been introduced at the University of Technology, Sydney (UTS). This subject has been designed to address the needs highlighted in numerous government reports on innovation and competitiveness. Three interrelated innovation abilities are developed in a cross-disciplinary environment through team-based activities and industry-based examples – these are the ability to generate ideas, to manage innovation and to capitalise on ideas. "Introduction to Innovation" is a component of UTS's new innovation education programs for cross-faculty technical undergraduates, and is a required component in the Faculty of Engineering's new Innovation Major for the Bachelor of Engineering.

UTS is at the forefront of innovation education initiatives with the real-world interaction with industry and the creation of an innovative climate within the "Introduction to Innovation" classroom. This subject provides tools and resources for potential innovators in an environment that enhances idea generation by encouraging students with different technical skills to actively engage with each other, and to appreciate each others' perspectives. The cross-faculty collaboration behind this subject could provide a model for other innovative educational developments to meet the changing needs of engineers, scientists and other technical undergraduates.

Introduction

"Introduction to Innovation" is a unique cross-faculty subject that has just been introduced at the University of Technology, Sydney (UTS). This subject speaks of "Innovation" in both its content and in its educational approach. It has been designed specifically to allow engineers and scientists to learn from each other and to learn about innovation together in a context relevant to technical undergraduates. "Introduction to Innovation" is the first major step in the new approach to innovation content within the faculties of engineering and science at UTS and truly represents 'learning across the boundaries'. This paper will focus on the background and rationale for the subject, UTS's new approaches to innovation, and on the innovative cross-faculty collaboration in the design and delivery of "Introduction to Innovation".

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The Increasing Importance of Innovation

Definitions of 'innovation' have evolved to recognise the many facets of activity that bring about increased productivity and generate wealth. Innovation is the "process by which ideas and the outcomes of development are converted to goods and services, or are otherwise used in the operation of a business. Improving the way a firm operates, such as changing distribution, management structures or services, are also innovative activities. It is driven by a need for ongoing improvements in productivity and competitiveness."[1]

The nature of innovation is changing due to the accelerating pace of technological change and the emergence of new fields such as biotechnology and nanotechnology combined with the increasing demands from a sophisticated and global customer base.[2] At the same time, developed nations are becoming increasingly dependent on innovation[3] Innovation is a strong contributor to productivity growth, and technological innovation is one of the main drivers of long term economic growth[4] Science, technology and engineering are particularly relevant as they are key drivers of innovation.[5] There are two main components of innovation – the creation of knowledge, and the commercialisation of the knowledge. Capabilities in both of these areas must be developed and linkages between the components strengthened for productive innovative activity.

Australia is strong in science and technology but Australian businesses are not strong innovators compared to other OECD countries.[1] The New Knowledge, New Opportunities report[6] emphasised that the ability to innovate is critical to Australia's economic health. The report noted that Australia is undergoing a transition from a resource based economy to a knowledge based economy. This change presents new challenges, and the enhancement of the creativity and skills of the people of Australia are becoming more important than ever.

Australian Government on Science, Engineering and Innovation

In 1997 the Prime Minister's Science, Engineering and Innovation Council (PMSEIC) formed a working group on the nexus between science and its applications to develop a strategy to strengthen the development of people skilled in both science and technology and management and to consider how to promote an entrepreneurial culture in school and post-school education. The working group concluded that the commercialisation of innovation in Australia can be improved by educating scientists and technologists to gain an understanding of the language and skills of business. The working group report recommended that "the Government recognises and supports the high value of interactive training of scientists, technologists and business professionals in the commercialisation of science and technology".[7]

In more recent years other Australian government reports into education and innovation have also highlighted the importance of educational initiatives. The Knowledge and Innovation statement[8] included specific recommendations about the need for increased research funding and for the introduction of innovation education across the education spectrum. The Innovation Summit Implementation Group stressed that it is absolutely essential to develop innovation awareness across all sectors of the community.[9,10] The PMSEIC working group on science engagement and education noted that although Australia has the correct ingredients for a successful high technology economy, these need to be combined with a more innovative business culture. The working group recommended that links should be strengthened between business and science education institutions. It proposed that better

cross-disciplinary links would increase career opportunities and improve Australian corporate performance.[11]

In 2001 the Australian government launched a major policy initiative to focus innovation funding in the Backing Australia's Ability (BAA) program. The BAA program recognised that although various government programs had already been introduced to enhance innovation, "more needs to be done in response to an increasingly competitive world environment and the recognition that success in the 21st century will depend predominantly on the innovative capacity of nations, their industries and their research and educational structure." [12] The BAA program outlined a 2.9 billion 5-year program designed to build Australia's capacity to generate new ideas and bring them to life. Additional funding for research and education was a large part of the program. One of the initiatives of the program was to increase funding to universities by $151 million to create 2000 additional university places each year. These new university places were designed to increase the innovative ability of science and technology students. UTS's initial offerings of innovation degrees in 2002 were a funded by the BAA program.

Planning for the Future – Mapping Australia's Science and Innovation

Under the BAA program, the government announced a project for mapping Australia's science and innovation system in order to plan for science and innovation initiatives beyond 2005-2006. The mapping Australia's science and innovation report released in November 2003 [5] noted the increasing need for cross-disciplinary courses in higher education and cited the lack of university courses aimed at developing both science and innovation skills. The report acknowledged that several universities have developed approaches to add entrepreneurial and business skills to technical undergraduate education, some in response to the BAA program. However, most approaches to this type of education currently fall short of truly embracing the cross-disciplinary nature of most innovation processes. In most offerings, technical students are offered a suite of business subjects along with their traditional technical subjects. The missing element is the integration of the technical and business subjects. The Mapping Australia's Science and Innovation report noted that there are many double degree courses offered, but there are few examples that integrate technical skills with 'soft' skills. [5]

Innovation Education – Crossing the Boundaries

Innovation is a hot topic in education in Australia and overseas. Governments in developed nations around the world are recognising the need for more scientists and engineers that can promote innovation and entrepreneurship. Policy recommendations include multi-disciplinary education initiatives to enhance innovation and competitiveness. For example, the Government of Canada [13] recognises the need to consider knowledge as a strategic national asset. Its Knowledge Matters report [14] highlights the importance of multidisciplinary learning and teaching techniques in the development of abilities to think creatively and work collaboratively. The German Federal ministry of education and research [15] also includes a similar focus on cross-disciplinary education policies to enhance innovation in its "Agenda 2010: Innovation Initiative" report. The United States Council on Competitiveness [16] believes that universities need to be adept at cross-disciplinary research and education in order for the nation to lead in innovation

These types of recommendations are echoed in Australian government studies. Australian studies repeatedly acknowledge that Australia's researchers are producing truly excellent work. However they also recognise that there is a lack in the abilities to bring research into commercial success. The Knowledge and Innovation report stressed that "An entrepreneurial approach is needed to harness the full cycle of benefits from [scientific and technological] endeavours through commercialisation".[17] In order to develop a culture of entrepreneurship, innovation education is recommended in a multidisciplinary context. Recommendations include the need for innovation awareness education for all science and engineering undergraduate students.

Innovation Skills and University Structures

While most technological innovations can be traced back to a beginning in science, innovation requires a broader range of skills. Innovators need skills in management, problem solving and risk taking along with skills in science technology and engineering.[18] The United States Council on Competitiveness[16] proposes that people are not born with inherent innovation skills, but that they can learn them. According to the Council's National Innovation Initiative, the innovation skills that should be taught range from the social skills and leadership skills that are required to work in multidisciplinary innovation teams to the communication skills required to describe innovations. In addition, the report recommends that innovators should learn to be comfortable with ambiguity and to use analytical skills to recognise opportunities and solve problems.

In addition to these general innovation skills, an enhanced business focus is achieved at some universities by the inclusion of entrepreneurship studies for technical and science students. Entrepreneurship studies include the business processes required to enable innovation, and usually focus on the creation of a new business or business venture. Financial, marketing, legal and management aspects of innovation are usually included in entrepreneurship studies. Kingon, Markham, Thomas and Debo[19] highlight the differences between entrepreneurship education for engineering or technical students and entrepreneurship education focused at business students. Their findings show that entrepreneurship education is approached differently to cater for the contexts of different groups of students. They found that the objective of the technicaly-based entrepreneurship studies aimed at undergraduates is to "create awareness and enthusiasm for entrepreneurial activities, rather than a comprehensive knowledge and skills base for new venture creation."[20] This type of technical entrepreneurship education usually highlights team and leadership skills and places far greater emphasis on opportunity development and the value creation associated with the idea, where business education focuses more on the business planning process.

The "Mapping Australian Science and Innovation" final report released in 2003[5] identified three interrelated abilities underpinning science and innovation. The three ability areas are:

Idea Generation – encompassing abilities in creativity and problem solving

Capitalising on ideas – including entrepreneurship and leadership abilities

Managing innovation – the ability to manage individuals and teams within an innovative culture.

Figure 1 provides an overview and illustrates the interrelationships between these ability areas.
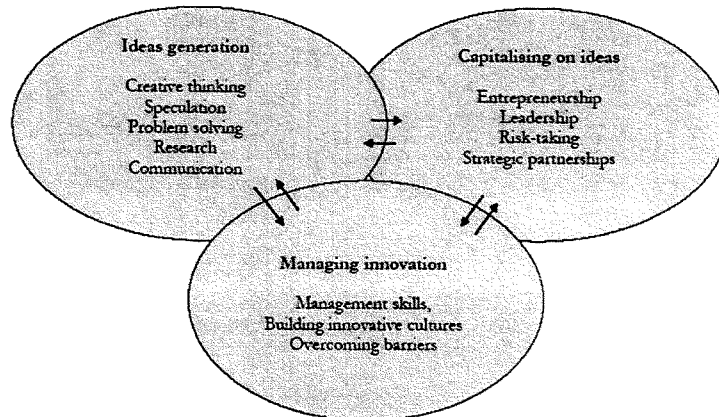
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Figure 1: Three abilities underpinning science and innovation.[21]

Universities are not traditionally structured in a way that facilitates the integration of entrepreneurial skills development into higher education science and engineering courses. The mapping Australia's science and innovation report[5] recommends that a cultural change is required within educational institutions to enable them to develop and run cross-disciplinary degrees to promote innovation. In addition, the report notes that staffing such courses can be difficult because most university teachers do not have the appropriate cross-disciplinary background and experience. According to the report, limited progress is being made towards development of entrepreneurial skills in science and engineering students in Australia.[5] The US Council on Competitiveness[16] also recognises the organisational structure of universities as a potential barrier to innovation. The National Innovation Initiative report recommends that Universities re-think how they are organised and consider the best structure to inform students about the process of commercialisation.[16]

A New Structure for Innovation - The UTS Innovatio n Degrees

Under the BAA program, UTS introduced "Innovation degrees" in Nanotechnology, Biotechnology, Engineering and Information Technology (IT) in 2002. These degrees were jointly developed and coordinated by the Faculties of Business, Science, Engin eering and IT. The initial design of the innovation degrees included a common 'business core' which made up approximately 1/3 of the three-year degree structure, with each discipline determining the rest of the subjects. This innovative set of degrees wa s the first attempt to provide cross-disciplinary 'innovation' education to technical undergraduate students at UTS, and represented several important advancements in innovation education. The "Innovation degrees" provided students with a unique multidisciplinary learning environment and a good overview of business innovation. The degree structure provided a framework for the four faculties (Science, Engineering, IT and Business) to work together. The UTS Innovation Steering Committee and the UTS Innovation Coordinators Committee include representatives from each faculty. These committees direct the innovation degrees and also consider how external developments will inform innovation education at UTS.

A review of the initial innovation degrees has resulted in changes to improve UTS's innovation offerings. The main weakness of the initial degrees was that the standard three-year degree structure did not allow enough room for the technical disciplines to be developed - particularly for the science and engineering disciplines. In addition, there were no specific links between the business core and the technical side of the programs.

Innovation Education at UTS 2005

During 2005 and 2006 UTS is introducing a new suite of innovation degrees within the Science, Engineering and IT faculties. The new degrees have been developed with the benefit of feedback from reviews of the initial innovation degree offerings. Each faculty is developing innovation programs to best suit their needs, while retaining and strengthening the innovative cross-disciplinary learning environment. Two new subjects, "Introduction to Innovation" and "Innovation Processes" have been specifically designed to promote innovation in engineering and science students and to integrate technical skills with 'soft' skills. These subjects form a bridge between other engineering, science and business subjects and introduce specific methods and tools that address innovation.

Under current proposals, each UTS innovation degree will incorporate several common elements including the new cross-disciplinary subject "Introduction to Innovation" that is overviewed in this paper. The new UTS innovation programs will range from three to four years of study plus innovation work experience options.

The Faculty of engineering's new approach incorporates innovation within its flagship degree, the Bachelor of Engineering, Diploma in Engineering Practice (BEDipEngPrac) with the introduction of an innovation major in 2005. The innovation major allows a student in any engineering discipline to add an 'innovation flavour' to their engineering education with an innovation stream of education. The Bachelor of Engineering, Diploma in Engineering Practice with a Major in Innovation takes 5 years and includes one ye ar of engineering working experience, including 6 months with an innovation focus.

The two new cross-disciplinary innovation subjects ("Introduction to Innovation" and "Innovation Processes") are required subjects in the engineering Innovation major. This major also draws on business subjects for the development of some of the innovation abilities As stated in the mapping Australian science and innovation report [5], the best approaches to innovation and the abilities required vary across different contexts. It is recognised that often the capitalisation of new or improved ideas will be done by different people than those that created the ideas. The incorporation of innovation education within engineering has been done with the engineering context in mind, recognising that engineers often form the bridge between science and commercialisation.

In parallel with Engineering, the Faculty of Science at UTS is re-thinking its innovation education offerings based upon experience gained from the initial degree. Employers want science graduates with sufficient technical skills as well as an awareness of innovation. However a science/innovation degree that is longer than the regular three-year science program may be unattractive to most students. By developing "Introduction to Innovation" from the context relevant to scientists and engineers, science students are able to refine scientific understanding as well as gain innovation awareness in one subject. The industry examples and guest speakers' innovation experiences are complemented by lectures that delve into the underlying science of these examples. Engineering perspectives are also

integrated into the learning and provide a bridge between science and innovation. In this unique environment, science students can gain relevant innovation understanding without lengthening their degree and currently all nanotechnology students take "Introduction to Innovation". The faculty of science is committed to the maintenance of cross-disciplinary innovation links within UTS and is also considering proposals to introduce a more in-depth innovation degree. A four-year science and innovation honours program is one option being considered. In such a program, "Introduction to Innovation" would be the first 'innovation' subject, enabling science students to then build further upon the initial innovation awareness they gain from this subject.

The Faculty of IT is currently reviewing a proposal to incorporate innovation as a sub-major within the Bachelor of IT. The standard IT syllabus includes a stream of subjects that overview the process of development a product from the original idea towards a commercial product. The innovation sub-major allows IT students to build additional innovation skills, and "Introduction to Innovation" is one of the subjects in this proposed sub-major.

Introduction to Innovation

The first offering of "Introduction to Innovation" is currently being taken as a required subject in the early stage of study by students majoring in Innovation Engineering and Nanotechnology. Other science, engineering and IT students are eligible to take this subject as an elective. The subject has been designed to build the three abilities highlighted in the mapping science and innovation report. [5] These abilities will be developed from a science and engineering context as outlined below:

- **Idea generation and creativity.** New ideas underpin innovation, but all new ideas are not radically new. Most innovation is incremental, and involves continual stages of improvement in a product, process or service. Radical innovations bring about major changes to related businesses, markets and organisations, and happen much less often. Sometimes an innovation is seen as 'disruptive' because the amount of change shakes up the industry, and threatens the established players in that industry. [22] [23] In this subject, students become aware of the range of innovative ideas and developments – from incremental to radical to disruptive innovations. Students learn methods to enhance creativity and develop an appreciation of the range of ideas that are valued for innovation. It is not necessary to be naturally 'creative' or 'original thinkers' – all students learn tools to enhance creative thinking and to generate ideas for productive innovations.

- **Capitalising on ideas.** The scope of entrepreneurship activities is put into perspective in this subject. Finance, marketing, intellectual property protection, logistics and management are overviewed in this subject within a context relevant to scientists and engineers. With this overview, students will be able to put the business subjects that form part of their degree into the overall innovation framework. Students also learn to evaluate opportunities and to recognise potential innovations through case studies and guest lectures. Guest lecturers from innovative high-tech companies present their experiences in commercialising their technology. In parallel, the students learn about the company's particular technology and the aspects of the technology that provide competitive advantage and differentiate it from other technologies. These real life examples are used as a vehicle for students to learn how to evaluate the advantages, disadvantages and challenges associated with particular technologies and how to evaluate opportunities and identify rival technologies.

- **Managing innovation.** The importance of multi-disciplinary teams for technological innovation is well recognised. [22] [24] This subject focuses on the development of team skills in class members, and a teamwork project enables students to put teamwork strategies into action. Additional modules help students learn to appreciate the many different organisational forms and cultures, and to understand how these affect innovation.

- **Bringing it all together.** The three abilities interact with each other in the process of innovation. [5] In addition to the activities outlined above, in "Introduction to Innovation" all three abilities are also further developed and reinforced through the classroom environment and the integrative group project

  - Class dynamics: An innovative culture is created within the "Introduction to Innovation" classroom with the application of aspects from all three of the highlighted abilities. The subject is designed to foster creativity through a supportive atmosphere where risk-taking is encouraged. Communication and leadership skills are developed through presentations and responsibility for group tasks. Specific creativity tools are learned and applied and problem solving exercises are conducted in a group environment.

  - Group project: Skills in the three main ability areas are applied in a group project investigating a particular technology and generating proposals on possible opportunities to exploit the technology. In this project, students apply skills in idea generation and problem solving, capitalising on ideas (particularly opportunity recognition), and the management of innovation through teamwork and organisational analysis.

As this subject is currently being run for the first time, formal student feedback data has not yet been collected - however we feel that the students in the class benefit in many ways from the cross-disciplinary environment in "Introduction to Innovation". Class examples and projects focus on developments and opportunities in the nano-sciences. Nanotechnology is a disruptive technology that affects many engineering and science disciplines and processes, and provides an excellent example of a new field where there are many entrepreneurial examples and opportunities.

"Introduction to Innovation" is at the forefront of innovation education initiatives with its real-world interaction with industry and the creation of an innovative climate within the classroom. This subject provides tools and resources for potential innovators as well as an environment that enhances idea generation by encouraging students with different technical skills to actively engage with each other, and to appreciate each others' perspectives. "A new generation of innovators must learn that they operate in a larger world. It is important not only to understand that world, but also to communicate effectively within it." [25]

Conclusions and Recommendations

"Introduction to Innovation" is a truly innovative approach to the important task of educating technical undergraduates about the business environment and the innovation process. The subject forms a common component of UTS's cross-faculty suite of innovation degrees, and has been designed to meets the needs identified by numerous Australian and international innovation reports. [for example 5 8 16] The cross-faculty collaboration behind this subject could provide a model for other innovative educational developments to meet the needs of engineers, scientists and other technical undergraduates as they prepare to enter these transforming professions.

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