This is the authors' manuscript version of the work. Published as:

Collet, Chris and Wyatt, David (2005) "Bioneering" – teaching biotechnology entrepreneurship at the undergraduate level. *Education + Training* 47(6) :pp. 408-421.

"Bioneering" – teaching biotechnology entrepreneurship at the undergraduate level

Chris Collet and David Wyatt

School of Life Sciences, Queensland University of Technology, Brisbane, Australia

Autobiographical notes:

(1) Chris Collet is an Associate Professor at QUT teaching genomics, bioinformatics and bioentrepreneurship.

Associate Professor Chris Collet, **(Corresponding author)**
School of Life Sciences,
Queensland University of Technology,
GPO Box 2434 Brisbane, QLD Australia 4001

e-mail: c.collet@qut.edu.au

(2) David Wyatt, a former founder and CEO of PanBio P/L, is now Adjunct Professor in BioBusiness at QUT teaching bioentrepreneurship.

Adjunct Professor David Wyatt
School of Life Sciences,
Queensland University of Technology,
GPO Box 2434 Brisbane, QLD Australia 4001

e-mail: d.wyatt@qut.edu.au

"BIONEERING" – TEACHING BIOTECHNOLOGY ENTREPRENEURSHIP AT THE UNDERGRADUATE LEVEL

Abstract

Purpose – We have developed an educational model that operates at the undergraduate level and aims to produce graduates who can comfortably operate in the gulf between laboratory bench and the commercial marketplace. This paper describes the course, approaches, activities and initial outcomes of the Bachelor of Biotechnology Innovation at Queensland University of Technology.

Approach – Students undertake "hard science" subjects and business subjects on entrepreneurship, innovation and market development. Synthesis of these disparate disciplines is driven through formation of virtual companies that serve to contextualize subject content and provide start-up company experience across the four year course. Student companies design biotechnology products and processes and can progress their product through initial research and development phases or undertake an industry-based internship working as a team on initial concept projects. This focused, team-based approach to learning is contrary to traditional science courses that focus on the individual.

Findings – Outcomes include graduates of high quality that have moved into positions associated with commercialisation and technology transfer where previously a PhD and MBA were required qualifications. Other measures of course success include acceptance and promotion of the new course by business, academia and government.

Originality/value – Postgraduate courses provide the most common pathway for assisted self-development of entrepreneurial skills in science and engineering graduates. In contrast, this model aims to train entrepreneurs in technological disciplines at an undergraduate level in a framework where innovation and enterprising behaviour are embedded in the fabric of the degree.

Keywords Entrepreneurship, Enterprising behaviour, Innovation, Biotechnology, Undergraduate teaching

Paper type Case study

Introduction

Science and engineering graduates and postgraduates who are entrepreneurially inclined and interested in commercialization and technology transfer usually follow a career pathway that involves undertaking postgraduate courses in business, commercialisation and entrepreneurship; often after a few years in industry. Entrepreneurship education through the traditional University-based business school route has been argued to have an enabling and accelerating impact on the activities of graduates *already* considering establishing businesses (Deakins, 2000; Galloway and Brown, 2002; Luthje and Franke, 2002). In many instances, however, the value of these arguments is questionable as they do not show actual entrepreneurial outcomes but are often based on surveys of future intentions at course exit; for example see Galloway and Brown (2002) and Mitchell and McKeon (2004). Recently, Gibb (2002) has argued that the current business school based approach to entrepreneurship education is slow to react to current social, political and economic needs. Gibb called for new paradigms in entrepreneurship education within a wider University context that focused on enterprising behaviour. Universities are beginning to embrace the notion of recognizing and developing enterprising behaviour within non-business disciplines and are introducing subjects on entrepreneurship into engineering, bioscience, law and music courses (Meyer, 2001; Mitchell and McKeon, 2004; Keogh and Galloway, 2004). The results from these initiatives have not, however, been reported. Here we report a model for teaching entrepreneurship in the context of an undergraduate science course.

Biotechnology is seen as a major pillar of economic growth in many countries. To seize the opportunities predicted for the “biotechnology century” national governments, including the Australian Federal Government (Backing Australia’s Ability, 2001, 2003), are investing billions of dollars into strategies to enhance biotechnology research, development and commercialization. In the development of regional biotechnology industries, small-to-medium enterprises (SMEs) will be the driving force with start-up companies figuring predominantly in bringing biotechnology products and processes to the global marketplace. New ventures such as biotechnology start-up companies or projects in established SMEs require champions with a sound knowledge of the relevant science and a familiarity of business principles relating to product innovation, market development and venture capital. Above all else, a strong entrepreneurial ability is required in an industry that is in its infancy. Commercialisation of research is essential to the development of local biotechnology industry and there is a critical need for graduates who can drive this process.

The traditional roles for the modern University include: (1) ideas generation, (2) research and development for transfer to industry and (3) the training of graduates for industry. The former two roles often lead to spin-off companies generally led by the academics who generated the novel

idea. The latter role is focused on established industry and is targeted to producing graduates who can fill industry-based positions in narrow technically-focused job markets. University-trained biotechnology graduates may generally possess a solid knowledge-base but often lack real-world business acumen and are often not entrepreneurially inclined, preferring instead to pursue careers focused on science. As such, the average biotechnology science graduate is generally not suitable or capable of operating in the commercialization environment between research and the market that is the focus of start-ups and established SMEs.

An innovative approach to education in biotechnology entrepreneurship has been implemented by the Science Faculty at the Queensland University of Technology. The Bachelor of Biotechnology Innovation (BBI) was designed in accordance with the philosophies of the Australian Federal Government's policies on innovation (BAA 2001, 2003) and the Queensland Government's Smart State Initiative (QLD, 2003) in that it aims to produce graduates who can drive commercialization of research outcomes. The course seeks to train biotechnology entrepreneurs who could be business-savvy scientists, or could operate in the gulf that is the commercial world between laboratory bench and global marketplace or could start their own companies to bring their own products to the marketplace. All of these potential roles serve to develop and strengthen the local biotechnology industry.

The BBI challenges traditional concepts in science-based University learning processes in a number of areas relating to (1) active versus passive learning environments, (2) team-based approaches to learning, (3) accelerated rates of learning, and (4) self- and peer-based assessment. The students in the course call themselves "bioneers" – as they regard themselves as pio***neer***ing a new era in ***bio***technology. This paper presents the course philosophy, approaches, activities and initial outcomes as the first batch of graduates begin their careers in industry.

Creating the "Bioneers" 1 – Course Design

The BBI was born out of an industry demand for scientists who had an appreciation of the commercial imperative. Industry feedback, while generally satisfied with technical skills in biotechnology graduates, noted a lack of understanding and skills appropriate for the demands of a commercial environment. Industry priorities are fundamentally different from the academic environment where training is undertaken. Skills in product development and commercialization, business, intellectual property law and management are considered desirable. The fledgling biotechnology industry has a special requirement for

entrepreneurial skills to facilitate recognition and development of emerging technologies thereby providing value-added opportunities for the local industries.

In course design, it was considered essential to maintain the high level of technical expertise and overlay this with skills in areas of business relevant to the commercialization of research. The four-year undergraduate BBI course, covering 32 subjects (4 subjects X 2 semesters X 4 years), contains the same hard-core biotechnology science subjects as those undertaken in a normal three-year science-based Bachelor's degree (ie, 19 subjects). Eight business subjects covering management, accounting, marketing, innovation, entrepreneurship, venture skills, business planning and research commercialization are included in the BBI course. The basics of intellectual property (IP) law and contractual law are also dealt with in a stand-alone subject. Four subjects cover a multi-year project related to the operations and outcomes of virtual student companies (see below).

Creating the "Bioneers" 2 – A Synthesis of Disparate Disciplines

Integral to the success of the BBI course is the ability of students to integrate the seemingly disparate disciplines of science and business and to graduate as a complete package. Double degrees involving science and business already exist within QUT as at other universities. Within these four or five-year double degree courses students can focus on aspects of personal interest and obtain skills across broad areas. Feedback from students undertaking double degrees is that they are often unsure of the connection between the two disciplines; uncertain how to marry the skills into a package that can be sold to potential employers. In this case, synthesis does not occur until after a few years of industry experience. Feedback from industry was that new graduate employees were not prepared for working in the chaordic environment (from chaos comes order – www.chaordic.org) of SMEs or new project development in larger firms where skills related to multi-tasking at different levels, initiative and decision making in the context of equivocal situations are prized.

To drive the synthesis of disciplines, a unique and innovative concept was introduced to the BBI degree course involving a multi-year project called the Student BioEnterprise (SBE) Scheme. Students form companies (ie, teams) or join existing companies at the end of the first year of the course and work within that environment through the duration of the degree. Students adopt recognised company roles which allow them to focus on aspects of particular interest. Common to all companies is a recognised CEO who coordinates company process, activity, communication and outcomes. SBE companies are encouraged to think about potential biotechnological products (real or unreal), research ideas and their potential in the marketplace. The SBE companies are

required to operate under normal company rules where hiring, firing and changing companies are all part of the process and biannual reports on progress towards a product are required. Running the SBE Scheme is handled through whole-of-course weekly meetings throughout the teaching semesters. The weekly meetings are used to facilitate the activities and events described below. Student participation in the scheme is mandatory and the scheme accounts for four subjects or 1/8 of the assessment for the entire degree.

Other facets of the scheme facilitate professionalism. An annual presentation evening, called Stellar Start Ups, is held where companies make a 6 – 10 minute pitch to an audience comprising biotechnology industry representatives, research scientists, venture capitalists, recruitment agencies and IP lawyers. With potential employers in the audience, students are very aware of the need to present a mature professional performance. Although attendance is not compulsory, over 90% of the students in the course attend and all bar one or two exceptions wear business attire. Companies have pitched their science-based product seeking to find industry partners or business investors amongst the audience. Companies have also presented themselves as consultants, available to undertake projects on behalf of industry and bringing a set of relevant skills to the industry problem. Students are also encouraged to partake in industry events, local and national conferences and seminars where they learn about, and network with, biotechnology industry. Many science students, including those undertaking biotechnology courses, seldom get the opportunity to interact at a personal level with industry. These exercises in a student-friendly environment provide opportunities for students to meet industry and further reinforce the need for professionalism when dealing with industry.

As part of the familiarisation process, first-year students are introduced to the concepts and expectations of the SBE Scheme, undertake a number of team-building exercises, learn how to network and write résumés, and reflect on career aspirations. After the introductory phase, first years are introduced to the later student cohorts and course meetings are held on a weekly basis. Weekly meetings discuss the latest biotech industry news, SBE company updates and reports, and other issues related to the course and companies. Occasional guest lectures are given by visiting entrepreneurs, industry representatives, recruitment agencies and even community activists.

The SBE company environment serves to develop team-based operations where students apply the theoretical knowledge learned in mainstream subjects to their own product and company development. For instance, in the business subject on product development and innovation, students develop their own product ideas; undertake market and competitor analyses and feasibility studies. In the subsequent Venture Skills business subject, students draw up comprehensive business plans around their company. The biotechnology business subjects also allow SBE companies to explore models in business finance, development and commercialisation

using industry case studies. The biotechnology science units form the basis for ideas generation and exploring potential products of real biotechnological worth. The students undertake the various subject-based assignments and projects as the company team.

A Team-Based Approach to Learning in Student Companies

In this team-based environment the student and the company team immediately see the relevance of the theory in each subject and gain the experience of putting theory into practice. Mistakes in a virtual company environment bear no overt financial or personal cost and the students learn quickly by their experiences. Those students with an affinity for one discipline area instruct and mentor the others in the group on the subject content because as a group they need to manage the company. This level of theoretical reinforcement results in an overall higher understanding of disciplinary conceptual framework. Lateral thinking and exploring innovative approaches are always encouraged and in the virtual environment off-the-wall ideas can be safely researched and implemented. The students very quickly began to challenge our own ideas and proposed new ways of approaching problems. For example, rather than undertake an expensive media-based advertising campaign for the course in 2003, we opted to send, all expenses paid, two students from any level of BBI to the national industry conference for AusBiotech in Adelaide on the provision that the students promote the course. The completing students countered with a proposal that the money be used to fund all eight to the conference. The students hunted cheap flights and accommodation in a single apartment near the conference centre. At the conference the bioneers were armed with printed colour biographies, business cards and course brochures, attended most sessions and networked the delegates. Comments filtered back from conference delegates relating to the high profile student presence and were unanimous in their praise of the capabilities and professional standards of the students. Some of these students are still in e-mail correspondence with delegates that visited from New Zealand and the United States.

An impact of the SBE Scheme was apparent almost immediately in the student attitudes and grades. QUT ranks students on a scale of 1 - 7 where 7 is the highest. Within one year of operating within companies, the grade point average of students began to climb. As each cohort proceeds through the course the individual student marks increase to the upper levels and it is not uncommon for students to consistently rate grades of 6 and 7. One female student, Anna, provides an example of the type of comments received: “before the SBE scheme came along, I was a very average student. The SBE provided a reason for everything I learned and it turned me around and focused me…. “. Anna’s grades are now routinely 7. From being a quiet person who shunned the limelight, Anna as representative of a student company has grown to be a confident business woman. Her capabilities have led to an internship in QUT’s technology

commercialisation office and one role is to deliver a seminar to postgraduate students on IP law. Anna is yet to graduate from the course but she is being head-hunted for several vacancies in firms dealing with technology commercialisation.

Since BBI students undertake mainstream science and business subjects comparisons can be drawn between course groups. Typical comments from fellow academics delivering in the course, whether in the faculties of Science or Business or Law, revolve around the focus, intelligence, cohesiveness of the bioneers, friendly competitiveness amongst the group and their ability to think differently than the others. Business lecturers commented that the BBI students are operating at the Masters level with an understanding of concepts far above the level that the subject was delivered at. One Business lecturer commented "the students think quite differently", represent "a refreshing change" and considered "quite frightening" in the level at which they operate. One conversation with an advertising academic revolved around how the BBI students had negotiated the framework of the subject content as the current content failed to meet the more advanced requirements of the companies. Within the Science Faculty, the grades of the BBI students routinely fall in the top 1/3 of the various classes.

Projects – Industry Focused or Student Company Oriented

Another approach to injecting real-world experiences into the degree program relates to the "research" component of the course. While the SBE Scheme runs for the entire duration of the course, student companies undertake a "research project" in the last year of the course. SBE companies can elect to either develop their own product further or undertake a project of interest to an industry partner. Projects can be team- or individual- based where output reflects the number of students involved. Projects can be science-based or business-based or along the continuum.

Industry-based projects focus on industry ideas or the student company may have a proposal that falls within the industry's focus. Some examples where SBE companies undertook industry projects are:

- *Agnis* produced a business plan for a local biotechnology company on a diagnostic kit designed to test microbial contamination of Australian meat supplies destined for export. *Agnis*'s business plan proposed a product that could be packaged with existing company products as part of a complete approach to quality improvement and management of herds.
- *Genero* examined the IP status of patents on blood testing held by a medical organisation and was able to recommend a pathway for product commercialisation involving strategic partnering and licensing other patented technologies.

- *Innoteq 1* explored the feasibility of using patented growth factors in the cosmeceutical industry and provided a Brisbane-based start-up company with a new market focus. Although not initially considered by the start up company, cosmeceuticals as part of a growing industry in self enhancement potentially represents as large a market as the original post-operative market targeted by the company.
- *Innoteq 2* examined the licensing market for another Brisbane-based spin-off identifying established biotechnology companies that could potentially use the Brisbane company's patented technology aimed at improving yields from mammalian cell culture.

For any one project, tasks can involve review of the patent status and research status of technologies, establishing IP position, SWOT analysis, identification of critical success factors and risk assessment, identification of target markets, financial planning, competitor analysis, production costing, identification of potential licensing arrangements, examining venture capital arrangements and compiling documentation for due diligence. The industry partner takes on the role of mentor and in practice this has meant that a number of contact people in one organisation may interact with a student company to progress the different and diverse tasks. Industry partners are encouraged to treat the SBE company as they would any consultancy firm but provide a reasonable level of guidance to meet desired outcomes.

Projects with industry partners are initiated by the SBE company or the industry partner; there has been no matching of SBE companies with industry partners. The annual industry presentation provides a major opportunity for student companies to meet real companies, to discuss common areas of interest and how SBE companies can help the Industry partner. *Agnis, Genero* and *Innoteq* secured projects following pitches at the annual event. The success of the SBE companies in providing tangible outcomes for real biotechnology companies has seen industry volunteer projects. Existing industry partners continually affirm their commitment for more SBE companies to work on their projects.

The success of the industry-based projects has also seen academics begin to use SBE companies as means to explore the commercial potential of University IP. A program is evolving whereby SBE companies, in a mentorship/consultancy capacity, identify and explore the commercialisation potential in research programs in the QUT Faculties. Three SBE companies are investigating commercialization potential and processes for science research projects: *Agnis* on Chlamydial vaccine opportunities, *Genesys* on the potential of a synthetic polymer for healing generated by a chemistry PhD student while *Bionyx* are investigating the IP potential relating to ureaplasmas. This arrangement with the QUT commercialisation arm could only be initiated because of the positive outcomes generated from previous interaction between industry and SBE companies.

Since one aim of the course is to produce inventors, SBE companies may opt to develop their own products further. Consultation with academics in the Science Faculty is encouraged to ensure that the scientific basis of the invention is sound. Companies that elect to advance products are required to develop a research and development plan complete with some level of costings. For example, SBE *Genesys* proposed to develop a simple point-of-care diagnostic kit for the early detection of cancer. As part of their initial literature-based research, *Genesy*s found that presence of elevated levels of a single protein was common to early stage development of 95% of all cancer types. They obtained the services of an IP law firm, free of charge, to establish that their IP position was secure and sufficiently different from others in the field targeting the same protein. Further literature searching has refined their method of approach. *Genesys* has broken the research and development of their product into a number of business- and science-related tasks where individual members of the team are reporting on IP law, market analysis, feasibility studies, product costings. Others undertake laboratory projects to determine the validity and sensitivity of the test in different cancer types. Other SBE company examples include *Nutrex* who are looking at increasing the efficiency of ethanol production through yeast fermentation while *InCell* are exploring novel approaches to limit the side effects of adenoviral gene therapy.

Ideas do not have to be high-tech. For example, SBE *Xest* is interested in micropropagation of rare plant varieties for the ornamental flower industry. In such species, methods of propagation of interesting clonal varieties may rely on seed and division of plants, methods that are slow and labour-intensive. Micro-propagation of tissue culture material and regeneration of plantlets greatly facilitates the marketing of existing rare varieties throughout the world and would allow, through mutagenesis, the creation of new varieties. Within three months of laboratory trials, *Xest* had succeeded where many others had failed. Protection of the intellectual property is by trade secret as any patent could be circumvented. *Xest* are currently examining scale-up processes to be able to mass-produce plantlets and are negotiating with a local nursery operation to annually supply 5,000 plantlets of one species at $30 – $50 each and 60,000 plantlets of a second species at $5 each. Given that *Xest* comprises two bioneers in the third year of a four year course, this represents a remarkable achievement.

Ideas for potential inventions are often derived from lecture material in biotechnology science subjects. In each case, SBE companies approached the academic in charge of the subject to provide advice and mentor the student company on refining their idea. For further product development, SBE companies are encouraged to seek industry support for development and have pitched their products at the annual Stellar Start Up event. That SBE companies are coming through the course committed to research and development of their own product augurs well for the possibility of spinning companies out directly from the course. Such spin out companies will boost local biotechnology industry and encourage other SBE companies to emulate their pathways

to success. One of the stimulators behind the process of the SBE Scheme and the accompanying research projects has been that the ownership of the student IP remains with the students. QUT cannot lay claim to any part of the IP other than that generated by staff or postgraduate students who have assigned their rights to QUT. The idea is that the students should generate the IP. The students are told that if they invent a product of real worth, they own the IP and the product; they are the ones who will benefit.

A Few Paradigms Challenged

The BBI challenges traditional paradigms in science-based approaches to teaching in a number of aspects but most notably on the issue of teams. In traditional science-based courses, didactic lectures are the norm and are coupled with laboratory sessions where students work in small groups of two to four. By and large, team skills are not formalised or recognised beyond perhaps a minor component of one or two higher level subjects within a degree. Unlike the whole-of-degree team-based environment of BBI, support networks do not normally evolve. For students intending to progress to postgraduate degrees, it is considered essential by Science Faculty academics to be able to gauge the abilities, and thus suitability, of an individual student for the rigours of a higher degree. The most intelligent survive the system and progress into an environment that is even more remote from the real world. In postgraduate degree programs, students often operate as individuals on very esoteric projects. In real world companies, not just technology-based ones, problem-solving approaches and work practices revolve around teams and completely different skill sets are required.

The learning environment engendered by the SBE Scheme does not fit into the hierarchy of knowledge acquisition normally associated with University courses. In the traditional model of University education, data acquisition is the focus of the early years gradually building to interpretation and analysis in the ultimate semesters. The notion of research on a potential product means that specific knowledge may be required before students have encountered the unit dealing with that particular scientific or business disciplinary area. Students have to find and assimilate that information in the product research. This leads to an accelerated rate of learning. At the 2003 Stellar Start-Ups, *Genesys* claimed that “university teaching was retarding their learning process”.

The SBE Scheme provides for an active learning environment, in contrast to the normal passive environment associated with structured lectures, tutorials and laboratory sessions, where students are empowered to drive their own learning experience. The understanding of relevance drives a positive feedback loop. As a consequence the students consistently drive the tempo of the experience to new heights and are motivated to succeed. This contrasts the traditional passive-

focused science course where instilling and maintaining motivation is a major issue. In challenging the students to realise positive outcomes consistent with the course goals, we have maintained a requirement for outcomes of industry standard. We have not sought to be proscriptive in any area of the SBE company activities other than the need to meet normal company reporting requirements and ethical standards. Our approach has been to continually challenge the students to achieve better outcomes. Continuous feedback from the industry mentor and the student peer group serve to focus outcomes. Action research-style surveys, written and oral, are routinely undertaken as a means of course improvement. Implementation of student suggestions has impacted at all levels of the course including design and assessment. The process of conducting the SBE scheme has been continually refined by student suggestion.

Self and peer assessment play a major part of the SBE Scheme and is divided into the two components of process and outcomes. Assessment of the company processes relates to roles in company reporting, ideas generation and exploration, focusing on specific products of interest to the virtual company, management of the company projects, and skills relating to a team-based culture including communication, setting team goals, work sharing, conflict resolution and decision making. Assessment of the project outcomes relates to the product realised, that is the quality and substance of the project report itself. In both components, students within an SBE company rate their own performance level and that of their team members on a scale of 1 – 7 (highest). Internal company negotiations arrive at a mutually determined performance ranking. Individual team members are required to write reports on their individual contribution and role within the SBE company and the research project that justify the ranking. If all the evidence is provided that the company requirements are met, then the ranking is converted to the grade. If the Industry partner or academic supervisor agrees that all the requirements are met and the ranking claim by the students reflects outcomes, then the ranking is converted to a grade. The notions of self and peer assessment depart dramatically from the typical exam-centred appraisal of student performance normally undertaken in science-based higher education. By and large, the rankings have been regarded as appropriate and little moderation has been required.

Some Negative Aspects of the Program

While all bioneers recognise the value of the innovative SBE scheme, one recurrent theme coming from the body of students relates to the importance of time management skills. Specifically, this relates to the extra demands of undertaking mainstream subjects overlaid with the requirements of the SBE scheme. Failure to recognise at an early stage the need for strict time management impacts on all aspects of course progression.

The requirements to think laterally and operate in an entrepreneurial fashion often frighten students who entered the course but did not understand the nature or intent of the degree. Many students entering University do so seeking graduate outcomes leading to secure stable careers. Such students are more comfortable with a directed and slow progression from data gathering to data interpretation rather than sifting through a wealth of equivocal situations to derive unequivocal events. The chaordic nature of biotechnology start-up companies as modelled in the SBE companies is anathema to such students. Unfortunately, they do not realise that stability is often far from reality in this age, even in Government. The SBE environment favours fast thinkers and extroverts. Those that seek the comfort of set guidelines and rigid structures do not cope well.

A "safety net" program is in place to catch those SBE companies that disintegrate through problems of incompatibility of team members. While conflict resolution is an issue that many SBE companies deal with internally and survive, in some instances conflicts lead to students being fired from a company or company members going their own way. As in real-world companies, the common causes for dissent reside in behaviours at the extreme of the norm such as the power hungry CEO or the team member that fails to contribute. Less than half of the SBE companies would progress through the course without some form of "restructuring". Within the framework of the SBE Scheme there is scope for projects of an individual nature. Part of the reflection undertaken during SBE process is recognising why a company may fail, as many SMEs in the real world do as a consequence of incompatibility problems with founding team members.

Course Outcomes and Impact on Stakeholders

Graduate destinations are a good measure of course success. The first cohort of eight bioneers, representing students who transferred into the course or undertook an accelerated program completing the degree in three years instead of the normal four, graduated in February 2004. Two of these bioneers are undertaking PhDs on projects with commercial outcomes that have spin-off potential. The lack of science research skills equivalent to the traditional Australian one year Honours research program was considered to be a minor issue in both appointments. Further laboratory training was deemed easier to provide at this level than developing a "start-up ready" entrepreneurial philosophy. The breadth of skills in science, business and IP law, the ability to think laterally and the high level capacity to communicate were the over-riding factors. Two bioneers have joined the offices of commercialisation and technology transfer arms of large research institutes. In the words of one employer: "*We decided to interview your students to benchmark them against PhD graduates with MBAs and commercial experience. We had no intention of employing them. Your students were the youngest, the least experienced*" but were "*the most focused, the sharpest*" and they "*could think laterally… They came out on top of the*

short-list." One graduate sent his CV to one commercialisation arm although they did not have a vacancy, after an interview a position was created. Two bioneers are Business Development Officers for Brisbane-based biotechnology companies; one established and one start-up, and are involved in identifying opportunities for future growth. One bioneer has been appointed Policy Advisor to the Minister responsible for promoting biotechnology in the state. As the latter bioneer relates "*Three e-mails went out to three VCs of Brisbane-based Universities seeking outstanding biotechnology graduates… I was interviewed along with applicants with PhDs and MBAs… I got the job, a mere graduate with a Bachelor's degree…".* The last bioneer decided to travel the world for a year. All employers have reported nothing but positive comments concerning the high standard of graduate capability, some are looking for more graduates to join the organisation. All graduates consider they have their "dream" job.

Another important measure of course outcomes is the part-time and full-time employment of students yet to graduate from the course. As a consequence of industry-based projects and the industry recognition of the student capabilities, many students graduating in February 2005 have already secured positions in biotechnology organisations in Queensland including positions in market research, commercialisation and business development. Interestingly, a network is developing amongst the graduates and current students whereby graduates and students in paid employment are preferentially hiring new workers, usually on a casual basis, from the BBI student cohort to undertake projects. The graduates maintain a strong connection with the course and each other, meeting socially once a month. As the current and future graduates move into and higher within the Australian biotechnology industry the collegiate culture of BBI will transfer itself into strong business and alumni networks.

The rapid uptake of the BBI graduates into positions in industry is probably the best measure of the impact of the degree on Industry. That the current undergraduates are attaining work in the biotechnology industry before graduation can also be used as a yardstick. A sound knowledge of a complex science and an understanding of business principles have been fundamental to the keen interest shown by industry in the BBI degree, especially in areas not strong in the science. One testament from a principal of a venture capital firm who was keen to employ a bioneer goes "*your graduates talk-the-talk of business and science – I am not a scientist*".

An independent audit of BBI outcomes, involving interviews of students, academic staff and industry, was conducted in late 2003 as part of the reporting processes for the Australian Federal Government and provides insights into Industry perceptions about the course (Clarke, 2004). A relevant excerpt from the Executive Summary of this report is presented here:

> *"The major outcomes of the industry representative perceptions were:*

- *Industry representatives had a general appreciation rather than a detailed understanding of the program, being more acquainted with the intent of the bioenterprise component with which they were directly involved as mentors and supervisors.*
- *Industry representatives had no preconceived expectations of students, preferring to rely on industry norms to gauge the students' actual performance on the projects.*
- *They were impressed with the students, particularly their initiative on following up initial industry contacts, their response to feedback and their inclination to see projects through to a successful conclusion.*
- *The industry representatives had limited exposure to the students written communication skills but were very impressed with their oral communication skills, their ability to manage time, to think creatively, critically and to problem-solve. Some were a little concerned with the depth of scientific knowledge exhibited but acknowledged the difficulty of developing such depth in two discipline areas. The extent of business knowledge impressed them. As far as the industry representatives were concerned, the students showed they could work both independently and as a cooperative team member, could locate and evaluate relevant information and utilise technology effectively. There was unanimous agreement that the students displayed various elements of entrepreneurship.*
- *What impressed the industry representatives most were the students' working knowledge of the biotechnology industry and their appreciation of the complete process of taking a product through from its initial development to final commercialisation.*
- *The industry representatives agreed that the biotechnology industry needed and was ready for such graduates and indicated that they possessed an employable set of skills."*

The BBI degree has achieved considerable State Government recognition and featured prominently in an annual report as an innovative degree program helping skill students for jobs of the future (QLD, 2003). The degree also features first amongst a group of State Government initiatives aimed at broadening business skills and instilling entrepreneurial skills (QLD, 2003). Recognition has also extended to meetings between successive new Ministers responsible for biotechnology promotion in the State and the student cohort, and an article in a high level State Government publication under the header "The future face of biotech" (QLD, 2004).

Conclusion

The national and state governments of Australia, like those of many countries, recognise the value of science and technology-led opportunities in building local and regional economies and are committing billions of dollars to research in emerging technologies (BAA, 2003; QLD, 2003). Science-trained academics are, however, traditionally ill-equipped to navigate an invention from

the laboratory to the global marketplace. In establishing the BBI degree, we aimed to produce bioentrepreneurs; graduates who would make a impact on the local biotechnology industry as business-savvy scientists, agents of research commercialisation or founders of their own start-up companies. Although the degree has only completed its first cycle, the course certainly appears to be meeting its goals. That the graduates and completing students are quickly finding positions within the small Australian biotechnology industry where previously a PhD, an MBA and several years of commercialisation experience were required qualifications is justification for experimenting with an undergraduate model that is very different from the traditional science-focused biotechnology degree offered by most Universities.

While many courses may include a subject or two on business planning, often masquerading as entrepreneurship (for example see Mitchell and McKeon, 2004), the concepts of innovation and enterprising behaviour are woven into the fabric of the BBI degree. Success of the degree clearly derives from the over-arching synthesis of the disparate disciplines driven through the concept of whole-of-course virtual companies that facilitates student empowerment, accelerated learning, support networks, peer assessment and industry projects that value-add. All the approaches and activities described in this paper instil a “hands-on/real world” applicable knowledge and skills base required for a “start-up” philosophy. If the heart of entrepreneurship involves action (Gartner and Vesper, 1994), then the most important enabling learning tool may be the activities associated with the SBE Scheme. The SBE companies act as emerging organisations and therefore the student learns, enjoys and becomes accustomed, at no financial burden, to the consequences of turning equivocal situations into non-equivocal events (Gartner and Vesper, 1994). Gibb (2002) laid down a challenge for teaching enterprising behaviour, rather than entrepreneurship, in a non-business school environment. The bioneers of the BBI are the first products of our experiment in training entrepreneurs in a science-based environment and their current success suggests that they may well add a new dimension to the growth of the local biotechnology industry in Australia.

Acknowledgements

Implementation of the BBI degree was generously supported with funds from the Australian Federal Government through the Science Lectureships Initiative and from the Queensland State Government’s Smart State Initiative. We would like to thank G. George and A. Herington for critical review of versions of this manuscript.

References

BAA (2001) "Backing Australia's Ability: An innovation action plan for the future." Available http://backingaus.innovation.gov.au/docs/statement/backing_Aust_ability.pdf.

BAA (2003) "Backing Australia's Ability: The Australian Government's innovation report 2003-2004." Available http://backingaus.innovation.gov.au/docs/BAA03-04.pdf.

Clarke, J.A. (2004) "Audit of the Bachelor of Biotechnology Innovation." QUT Faculty of Science.

Deakins, D. (2000) "Twente University Entrepreneurship and Commercialsiation Programmes." PERC internal report.

Galloway, L. and Brown, W. (2002) "Entrepreneurship education at University: a driver in the creation of high growth firms?", Education and Training, Vol 44 No 8/9, pp 398-405.

Garter, W.B. and Vesper, K.H. (1994) "Experiments in entrepreneurship education: Successes and failures", Journal of Business Venturing, Vol 9 No 3, pp 179-187.

Gibb, A. (2002) "In pursuit of a new 'enterprise' and 'entrepreneurship' paradigm for learning: creative destruction, new values, new ways of doing things and new combinations of knowledge", International Journal of Management Reviews, Vol 4 No 3, pp233-269.

Keogh, W. and Galloway, L. (2004) "Teaching enterprise in vocational disciplines: reflecting on positive experience", Decision Management, Vol. 42 No 3/4, pp531-547.

Lüthje, C. and Franke, N. (2002) "Fostering entrepreneurship through university education and training: Lessons from Massachusetts Institute of Technology", European Academy of Management 2nd Annual Conference on Innovative Research in Management, May 9-11, 2002, Stockholm. Available http://www.sses.com/public/events/euram/complete_tracks/management_education/franke_luthje.pdf.

Meyer, G.D. (2001) "Major unresolved issues and opportunities in entrepreneurship education", Coleman White Paper, USASBE/SBIDA Joint National Conference, February 8, 2001, Orlando FL. Available http://www.usasbe.org/pdf/CWP-2001-meyer.pdf

Mitchell, P.C. and McKeon, A.E. (2004) “Importance of peer support and tutor involvement in entrepreneurship education for overseas bioscience students” BEE-j, Vol 3, May 2004. Available http://bio.ltsn.ac.uk/journal/voln/beej-3.2.htm.

QLD (2003) “Queensland the Smart State, Investing in science: Research, education and training”, Queensland Government Publication. Available http://www.sd.qld.gov.au/innovation/publications/smartstate/science.pdf

QLD (2004) “The future face of biotech”, Catalyst, Issue 10, pp10-11. Available www.smartstate.qld.gov.au/smartstories/catalyst/2004/10.pdf