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Integrating Enterprise Education with Science and Engineering Degrees: A Case Study

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Abstract. Characterised by post industrial capitalism, the UK economy, as in other modern nations, is increasingly based on innovation, knowledge and enterprise. The UK government is focused on expanding the volume of science and engineering-based businesses (DTI, 2002; Rosa, 2003), as these knowledge intensive areas are seen as key to improving competitiveness within industries and nationally. There are obvious implications for education, and particularly higher education, in this context (Hannon, 2006). This case study focuses on the provision of enterprise education for students pursuing degrees in science or engineering at Heriot-Watt University. Heriot-Watt has a long tradition of educating scientists and engineers (O'Farrell, 2004), and the disciplines are well developed and internationally respected. The challenge has been providing a means by which science and engineering programmes have experienced enterprise education, in order that the realities of the modern enterprise economy are conveyed to the benefit of students and industry alike.

Keywords: enterprise, education, science, engineering, physics, curricula, entrepreneurship, business.

1. Terms of Reference

The focus of this paper is the integration and embedding of enterprise studies within science and engineering degrees at Heriot-Watt University, Edinburgh. It is important to note that Scottish university degree conferment varies slightly from elsewhere in the UK and beyond. First, most undergraduate Honours degrees take four years in Scotland, the third level representing Junior Honours, the fourth Senior Honours. Graduation after just three years results in Ordinary degree conferment. Additionally, the title Masters can apply to an undergraduate degree in Scotland, and some postgraduate Masters awards are studied without having graduated with a Bachelors first. Most notably for this paper, a Master of Engineering (MEng) degree is a qualification that takes five years to complete. It is regarded as of higher quality than a Bachelors degree in Engineering (BEng) as only highly competent students are allowed on the programme and it is equivalent to a postgraduate Masters. In science studies in Scotland, the usual UK format is used i.e., a Bachelor of Science (BSc) is conferred at undergraduate level (three years for an Ordinary and four for Honours), and an MSc is conferred for taught postgraduate degrees. However, within some Science disciplines it is also possible to study for a five year Masters degree (MSc), in the same way as for an MEng.

2. Introduction and Background

The UK government is focused on expanding the volume of science and engineering-based businesses (DTI, 2002; Rosa, 2003), as these knowledge intensive areas are seen as key to improving competitiveness within industries and nationally as a result of the emergence of the modern economy. Small firms increasingly are regarded as a main driver within this new economy (Keogh, 2002; Klapper, 2004), and particularly those in knowledge-intensive industries because they are seen to have "the capability to generate innovations that may be the basis of high growth firms" (Zacharakis, *et al,* 1999:32). Large firms also are adapting in order that they have the capability to respond and act in a manner similar to small firms, for example, by promoting enterprise via departments and project teams (Hall, 2004). As commentators such as Drucker (1994) and Roberston and Collins (2003:307) claim, competitiveness will be enhanced by "a workforce which will express itself in an innovative and creative manner irrespective of its current function – large firm, local authority, small firm or community-based organization". For the maintenance and development of knowledge-based professions and industries specifically, there exists therefore, a need to supply "graduate scientists and engineers with suitable and appropriate skills" for commercial exploitation (Chell and Allman, 2003:118).

The implications for students, particularly those in science and engineering, are considerable. Even within industries that have traditionally been dominated by large firms, the employment landscape is changing to reflect this wider economic cultural shift. For example, the Institute of Physics note that while large firms continue to be a common means of employment for physicists, "micro, small and medium-sized firms are equally important", and indeed "most [physics based] enterprises are micro or small firms." (Glen, 2003: 11).

The UK is known for its "strengths in generating knowledge and ideas within the science and engineering base" (Council for Science and Technology, 2003:3). The extent to which this generates commercial activity, however, has traditionally been weak. It is not the quality of science and engineering knowledge that is lacking,[1] but the levels of enterprise within the science and engineering bases (Chemical Industries Association, 2006). Therein lie implications for education, and particularly Higher Education. There has been a push to include business and specifically enterprise skills teaching and learning in curricula. Most notably, the Office of Science and Technology created in 2000 thirteen Science Enterprise

1. Though there are serious concerns about the quantity of qualified science and engineering personnel.

Challenge centres. In Scotland this gave rise to the Scottish Institute for Enterprise (SIE), a collaboration of originally five (now all) Scottish universities, which aimed to promote enterprise education within the science and engineering disciplines and increase commercialisation activity. As one of the five original members of the SIE, Heriot-Watt University created posts for enterprise specialists with a remit to deliver enterprise education to students in science and engineering degree programmes. The current paper provides a case study of the means by which this has been achieved. It details the implementation of a planned, university-supported approach to integrating enterprise education with core vocational studies.

3. A Conceptual Framework for Enterprise Education

While there is no definitive list of skills and abilities that embody enterprise, and it is not within the scope of the current paper to provide one, there is general consensus within the enterprise literature that both tacit (e.g., confidence, initiative) and explicit (e.g., financial planning, market analysis) competencies are represented (e.g., Kirby, 1992; Simmons and Mason, 1999). Engineering and science professionals are as likely to require enterprise skills as any: in fact, many of these skills are cited by both the Engineering Council (UK) (2005a) and the Science Council (UK) (2006) as professional requirements of a Chartered Engineer and a Chartered Scientist respectively; both indicators of excellence within the engineering and science bases.

The debate about how to teach enterprise for effective application within the enterprise economy is ongoing (Gorman, et al., 1997; Young, 1997). To summarise the literature, commentators tend to agree that the practice of enterprise education is one that requires a blend of knowledge, skills and attitudes, which recognises the synergistic links between management theory, entrepreneurial practice, and, in the case of the knowledge-intensive industries, specialist skills and competencies (for example, Weinrauch, 1994; Gorman et al 1997; Bechard and Toulouse, 1998). Correspondingly, the context and content of enterprise education are prevalent issues in considerations of delivery to science and engineering disciplines.

Three dimensions from which enterprise education can be presented have been identified. These are *about* enterprise, where the focus is on types, effects, nuances, etc. of entrepreneurship and enterprise; *for* enterprise, where enterprise skills development for application in firm start-up and more recently enterprise activity within any organisational context are the main aims; and *through* enterprise, where students learn about entrepreneurship and enterprise via experience of entrepreneurship, innovation or enterprise in action (Levie, 1999). Handscombe, et al. (2005) add a fourth dimension of *from* entrepreneurship whereupon students learn about entrepreneurship and enterprise skills from exposure, direct or indirect, to vocational discipline-based entrepreneurship. In practice, enterprise education in UK universities can usually be split into four types. These include:

1. *evaluation-based* enterprise education which includes introduction and/or analysis of the economic contribution of entrepreneurship and enterprise, and is usually assessed via traditional university practice (i.e., essay and/or examination);

2. *simulation-based* enterprise education, which teaches 'how' to start or manage a new enterprise, and is usually assessed via team presentation and business plan or project report;

3. *placement-based* enterprise education, which involves placing students in entrepreneurial firms for 'real life' experiential education, and is usually assessed via individual report;

4. enterprise education with a variety of aims that uses a combination of methods.

For enterprise education for those in vocational disciplines it has been argued that the combination of methods is the most appropriate, as students need to be aware of the effects and potentials of enterprise within their discipline as well as have the opportunity to develop applied enterprise and business skills (Frank, 2005; Handscombe, et al., 2005). Moreover, it is also argued that pedagogy must address the variation in aims between business school education and enterprise within vocational disciplines (Biggs, 1999), as well as variation amongst the vocational disciplines themselves (Johnson, et al., 2006). When designing enterprise education for vocational students, there are therefore, several implications. Much delivery in both 'for' and 'about' enterprise education involves the use of case studies. These should be representative of the kinds of industries in which specific vocational students will participate and have experience. Similarly, where enterprise education research has identified the value of providing role models via the inclusion of 'real life' guest speakers (e.g., Williams and Turnbull, 1999), these should be industry/discipline appropriate. Importantly, when planning enterprise education for vocational students, particularly those in science and engineering, it must be taken into account in the teaching style design that students may have significantly different experience and style of learning from students of business disciplines (Ramsden, 1992). Specific measures must be taken, therefore, to ensure ongoing informal assessment of the teaching and learning experience so that additional support can be provided if required. Essentially, enterprise education for science and engineering students must be relevant to specific disciplines, to students' career aspirations, and to students' learning styles.

Handscombe et al. (2005) claim that enterprise education for science and engineering students can only be meaningful if it is integrated into the "overall learning experience…but not at the expense of core discipline learning". One way of achieving this is by embedding enterprise into the vocational curriculum. Embedding refers to mandatory inclusion of enterprise via whole modules or part modules in degree studies. Inclusion might include enterprise (especially core skills associated with enterprise) as part of professional development or careers skills modules, as well as independent 'about' and 'for' entrepreneurship modules. Embedding can afford a complementarity between enterprise education and vocational education. Embedded mandatory enterprise study has the potential to change the culture of the core discipline to better reflect the realities of its existence within the current economic climate to a greater extent than enterprise study as an "optional extra"(ibid). Embedding enterprise education within vocational degrees is still relatively uncommon. Increasingly commentators are pointing to the appropriateness of it as a strategy, not only for students of vocational subjects, but within business schools. This is as a result of the ongoing maturation of the enterprise/entrepreneurship discipline, and also the advantages of enterprise to competitive modern economies (Volkman, 2004; Frank, 2005; Johnson, et al. 2006).

4. Enterprise Education at Heriot-Watt: Specific Issues

Heriot-Watt University has a long tradition of educating scientists and engineers (O'Farrell, 2004): prior to receiving its Royal Charter in 1966 it offered higher education as a College of Technology. Within the university, therefore, the science and engineering disciplines are well developed and internationally respected. Until 2000, however, there was no provision of enterprise (or business) education for those pursuing degrees in anything other than business and management, except for a few elective management modules. The implications of the SIE remit for Heriot-Watt were, thus, substantial.

Another challenge involved the expectations of students who come to the university to study science or engineering. These students, reasonably enough, tend to be those who have studied science and engineering-related topics at school. For example, at Heriot-Watt the entry requirements for a new undergraduate to study BEng/MEng in Mechanical Engineering or a BSc in Physics are four Scottish Highers or three English, Welsh or Irish A-levels, or overseas equivalents. For both of these degrees, these four or three examination results must include Mathematics and Physics. It is entirely plausible that a student can come into the university to study for a science or engineering degree having studied science and engineering-related subjects exclusively for a number of years previously. This specialisation can lead to a lack of appreciation of the relevance of economic issues and non-science/engineering skills development amongst science and engineering students.[2] Science and engineering have traditionally been divorced to a large extent from the business community, a tradition that is evidenced in low levels of technology transfer and commercialisation of the science and engineering base in the UK. This tradition is now defunct. Government, the business community and both the Engineering Council and the Science Council are consistent in acknowledgement of the value and potential of knowledge and enterprise. The lag in understanding, however, amongst those involved in study and training within the knowledge disciplines is observable in any UK higher education institution. Consequently, engineering and science students can fail to recognise the importance to them of receiving enterprise education and may even resent the intrusion in their curricula. This is echoed within the literature, for example, Frank (2005) in Built Environment, and Handscombe, et al. (2005) in Mechanical Engineering confirm the potential for resentment.

It is common to experience, in the first few teaching sessions, resentment amongst students who believe the intellectual scope of business studies and its relevance to them is limited. Whenever enterprise education is delivered in science and engineering degrees at Heriot-Watt, the rationale for its delivery is explained and discussed with students. This is in line with good teaching practice generally, and is most pertinent in enterprise education because it can deviate substantially from many students' regular experience of teaching and learning (Hayward and Sundes, 1997). Thereafter, teaching materials, especially examples, are science or engineering based. Guest presenters are selected from science or engineering industries to provide appropriate role models, and assignments tend to specify that ideas be generated through applied exercises and examples used in academic exercises are student discipline-based. While not always fully tailored to each specific discipline, the teaching and learning experience of enterprise education in science and engineering degrees at Heriot-Watt is made overtly and explicitly relevant. Using this contextualised and direct approach to relating the relevance of enterprise studies to science and engineering students has been highly successful. Feedback within assessments shows high levels of awareness of enterprise within specific disciplines, and when using discipline-specific referents throughout classes, high levels of engagement and participation are observed.

As noted elsewhere by writers such as Corman, et al. (2005), Hannon (2006) and Johnson, et al. (2006), a further complication of enterprise education delivery for science and engineering students involves curriculum time. Most science and engineering degree programmes involve relatively large amounts of contact teaching and learning compared with other subjects such as those in the social science and business subject areas. Contact teaching and learning time within science and engineering disciplines can comprise lecture, seminar/tutorial time as

2. Though, certainly in Scotland, much work is done in the schools also to improve knowledge and understanding of modern economic conditions, and particularly the role of enterprise.

well as half-day or whole day laboratory time, and are supplemented by shorter (than other subject areas) private study periods. Additionally, degree programmes, like in other subject areas, are made up of a series of modules. Core science and engineering classes take up most of these modules, with some 'slots' being reserved for elective modules either of a student's free or restricted (by requirements of a specific degree programme) choice. Enterprise education at Heriot-Watt had to be delivered within these limited parameters, and in some cases whole modules could be delivered within a previous free elective slot, others could be delivered via restructuring degree programmes to omit obsolete elements, thus making room for enterprise. Where business education input had become imperative (as required by professional institutes – as was the case for engineering), enterprise education was prioritised in degree restructuring in order that delivery could be made as appropriate. For others, where there was less external pressure to formally include business education on degree programmes, less provision for delivery was made. For all science and engineering undergraduate degrees, though, some enterprise input has been achieved, and in all cases, some element of embedding enterprise within the degree programme has occurred.

The current paper provides two examples of where enterprise education has been successfully provided: in Engineering and in Physics.

5. The Engineering Example

5.1. The Professional Engineer

The importance of enterprise in university curricula is made manifest for engineering departments: several of the UK Institutes of Engineering now cite enterprise skills as a requirement of the education received prior to graduation and pursuit of routes to registration as a Chartered Engineer. Becoming a Chartered Engineer is essential for many jobs within the engineering industries, beneficial for others, and is an expectation amongst university students of engineering disciplines in the context of their anticipated career. The Engineering Council (2005b) states that "Chartered Engineers are characterised by their ability to develop appropriate solutions to engineering problems, using new or existing technologies, through innovation, creativity and change". Additionally, amongst other things Chartered Engineers "might develop and apply new and more efficient production techniques, marketing and construction concepts, pioneer new engineering services and management methods" (ibid).

To qualify for Chartered status, an engineer in the UK must be a registered member of a recognised professional institute, such as the Institute of Electrical Engineers (IEE) or the Institution of Mechanical Engineers (IMechE), and must have an accredited qualification from a university. The university qualification implies competencies as specified by the professional institute in which one is a member. Further, qualification for Chartered Engineer status also requires one to have developed professional competencies via employment-based experience. For example, the IMechE states that Chartered Mechanical Engineers should demonstrate commitment to the “innovative application of engineering and management sciences that underpin existing and emerging technologies” (IMechE, 2004). For those pursuing Chartered status they must have completed an appropriate Masters level qualification. They can then undertake Industrial Professional Development through the Institution’s Monitored Professional Development Scheme for four years within employment. Upon completion of required education and experience objectives, Chartered Engineer candidates must undergo a Professional Review with the Institution. For mechanical engineers the competencies that must be demonstrated include specific engineering competencies, leadership, interpersonal skills, and they must “make a personal commitment to professional standards” (IMechE, 2004).

For a university course to be accredited for qualification of Chartered Engineer pursuit, it must meet criteria as set out via UK Standards for Professional Engineering Competence (UK-SPEC) for each engineering institute. UK-SPEC are engineering institute-specific guidelines about degree programme inclusions and content required for accreditation as having Chartered Engineer qualifying status. To pursue the mechanical engineering example, the IMechE specifies that accredited courses provide specific Technical Objectives, and in equal number, specific Business and Personal Objectives. These include Management (including planning, management and implementation of an engineering project), Financial, Commercial (including the financial and commercial implications of market and customer response), Personal (specifically group working) and Legal and Social objectives (IMechE, 2004). Thus, within their degree programmes students of mechanical engineering, if they are to achieve Chartered status, must experience and demonstrate abilities such as creativity, innovation, project management, business planning, market research, team work, and commercial feasibility testing. Providing enterprise education is a highly appropriate way of achieving this.

5.2. Enterprise Education for Engineering Students

At Heriot-Watt for those pursuing a degree in disciplines such as mechanical engineering, chemical engineering and electrical engineering, enterprise education is now an essential element. This has occurred as a result of the push from the Engineering Institutes and from the engineering staffs’ commitment to continual professional development for students. Indeed, in the engineering case, senior members of engineering staff were given the role of liaising with enterprise staff to ensure appropriate and sufficient enterprise inclusion in engineering degrees. This appointing of champions to ensure effective and beneficial embedding afforded a fully collaborative embedding process that facilitated quality pedagogic design and content delivery.

At Level 1, enterprise is not mandatory. All engineering students, however, are offered the opportunity to take *Management* as an elective. This comprises introductory modules and an *Entrepreneurship* module, where students devise a commercial idea and develop a business plan. This optional entrepreneurship module is intended only to introduce the principles of idea generation and business planning via the business start-up model: ideas generated need be neither innovative nor growth-oriented and groups can comprise up to twenty students. During this module, however, students receive lectures on business planning issues and are thus introduced to concepts such as market research, financing a business and business reporting, and are exposed to business role models via guest lectures.

Embedded enterprise education occurs more formally in Level 2. At this stage of engineering degrees enterprise education is compulsory. All BEng and MEng students must attend the module *Professional Development*, whereupon the professional (including enterprise skills) development needs of the engineer are taught. In this module students learn about the economy in which they will participate, and specifically, the implications of that for them. As a result, there is input on this module from the university's Careers Service, and an emphasis thereafter on the value and development of transferable enterprise skills. During this module, therefore, both 'about' and 'for' entrepreneurship are taught, though both are delivered at an introductory level. For the former, basic understanding of the economic status-quo is the intended learning outcome in order that students are equipped to contextualise informed choices about their future careers. Much delivery is lecture-based, but it is supported by experiential learning in the form of role-playing and real-life scenario simulation, such as job interviewing and finance sourcing. For the latter 'for' enterprise aims, the intended learning outcomes include development of transferable enterprise skills. Tacit skills such as creativity for idea generation, team working and confidence are developed alongside explicit skills such as project management, presenting and report writing via simulated business feasibility testing. Assessment is based on team presentation (oral and written) of a group idea and demonstration of its outline commercial feasibility. The model students might use may be entrepreneurial, in that the simulation is business feasibility, or intrapreneurial, in that the simulation is project feasibility for an existing organisation. Either way, however, the idea upon which assessment is based must demonstrate innovation, technological or process, and must be engineering-based. Groups typically comprise four or five students and contact teaching time tends to be seminar-style (i.e., students learn in groups and the environment is generally iterative, with the lecturer taking on the role of consultant trainer). The seminar style of teaching and learning lends itself to understanding and skills acquisition as students learn to discuss and develop competencies, and learn to appreciate strengths and weaknesses within the team.

For both the 'for' and 'about' enterprise aspects of the *Professional Development* module active participation on the part of students is important, as it is well-documented that this facilitates deeper understanding and promotes the development of skills (e.g., Marton and Saljo, 1976).

By Level 4, engineering students at Heriot-Watt take on an engineering exercise as part of their engineering education. This usually involves them providing an engineering solution to a given product or process-based 'problem' (e.g., the creation of more efficient, productive or cost-effective cattle-feeding machinery). At this stage BEng and MEng students attend also the enterprise module *Engineering Management*. In this module they must prepare a commercial feasibility report based on the engineering project, working in the same project teams. With an assumed proven concept, students are required to consider how they would get their engineering project to market, and how they would manage it as a commercial opportunity with which to make profit. While providing further opportunity to develop presentation, written and research skills, this exercise develops the conceptual linkage between engineering and the business or commercial environment, as well as core business skills such as financial planning, marketing and consideration of human resource issues.

For those pursuing MEng, further mandatory enterprise education is provided at Level 5. The enterprise module *Enterprise and Industry* integrates more holistically with students' engineering education than in previous years. As part of their engineering studies, MEng students must create a prototype. Their enterprise education uses this exercise as the basis of an entrepreneurial business planning exercise. Initially, students develop their creativity skills in the enterprise module, and apply them via innovation in both their engineering project, and in their development of a simulated entrepreneurial business. Caveats within the business creation exercise include strategic objectives, such as planned growth over time via expanding markets or expanding product ranges, or planned exit, in order that the end result is a true entrepreneurial simulation. This entrepreneurial product development project approach means that students experience the whole product generation, development and commercialisation process within the context of the growth-oriented business simulation. Skills developed build on skills introduced in previous levels, and high quality business plans, including detailed product, market, capitalisation, financial and strategic elements are required for assessment. Indeed, as only the most competent engineering students qualify for pursuit of an MEng, and building on integrated engineering and enterprise studies, the quality of submissions has been consistently high, and several have been short-listed in local and national student business plan competitions.

In response to requirements of both the current economy, and of the engineering institutes, there has been a significant push to ensure the inclusion of enterprise education in engineering studies. As a result, embedding enterprise within the engineering degrees has been facilitated by co-operation and collaboration between engineering staff and enterprise specialists. For those where the imperative from their institutes is more flexible, however, a different approach has been taken.

6. The Science Example

6.1. The Professional Scientist

There is less focus on Chartered status for practice within employment for many of the science-based disciplines in the UK. For example, while one might benefit from being a member of the British Computer Society and achieving Chartered Engineer status through it, it is not considered essential to most graduate employment opportunities within the computer industries. Similarly, status as a Chartered Engineer or Chartered Scientist within the Institute of Physics may provide benefit, but is not essential for practice. As a result, for universities the education provision implications are less onerous than they are for many engineering subjects. Increasingly, however, the institutes of science, within the auspices of the Science Council (UK), are noting the importance of entrepreneurship, innovation and enterprise skills to the science industries. For example, in their report on the exploitation of knowledge, the Council for Science and Technology (2000:4) cite, as a priority, that the UK government should "seek to increase significantly the cadre of top class, technologically sophisticated people in the labour force…and seek to improve career pathways for students and researchers in science, engineering and technology, so that they gain skills, knowledge and contacts needed for running technology based businesses". Moreover, universities still have to provide education appropriate for practice within prevailing economic conditions within curricula where time is limited. While less extensive than in engineering, enterprise at Heriot-Watt is also embedded in science education. The appointing of champions within the specific science disciplines, again has afforded most success, and is represented in the example below.

6.2. Enterprise Education for Physics Students

The Institute of Physics report significant changes in the industry and employment landscape for physicists, notably a 165 percent increase in physics-based industry enterprises since 1989, particularly in photonics and nanotechnology (Glen, 2003:11). In response to these changing economic circumstances the Physics Department at Heriot-Watt requested the inclusion of enterprise education on their undergraduate degrees. As a result, students of physics and related disciplines (e.g., photonics) are obliged to attend the Level 2 module *Enterprise for Physicists*. This module sits alone in the physics curricula as the only one afforded by time constrictions. As such, this module acts as an introduction both to knowledge and understanding about the modern enterprise economy and the value of the knowledge industries within it, and also to enterprise skills development. This module is based on both contextual and conceptual/experiential teaching and learning, and students are assessed by both essay and exam, and by presentation and report: the former on the economic impact and potential of physics and the latter on the commercial feasibility of a team idea. Therefore, within one module 'for' and 'about' entrepreneurship are delivered. Students are taught, most often, via lectures. This teaching method is necessary due to the large number of students. It does not, however, preclude contextualised, participative learning experiences, and appropriate empirically reported methods were employed in the module design to facilitate the two main 'for' and 'about' intended outcomes (e.g., Marton and Saljo, 1976; Glasser, 1990). First, whether a topic is 'for' or 'about' is made explicit to students, as was the means by which each would be assessed. Where 'for' topics are concerned, in order to afford participative and iterative teaching and learning, breaks are made throughout lectures so that students can practice and develop the skills being taught. This practice is conducted in groups that have been assigned at the start of the module. A task is given, and each group reports outcomes via an elected spokesperson. This is an effective 'in class' means of participative learning that can benefit larger classes because reporting (and feedback) is observed not only by the lecturer, but also by the other students who may also comment. This facilitation of communication to afford depth of participative learning is commonly regarded as good practice in education generally, in that it facilitates contextualised knowledge, i.e., dialogue and interaction deepen understanding by the facilitation of analysis, refinement and deconstruction of concepts (Rumelhart and Norman, 1978; Laurillard, 1993; Mayes, 1995). As the submission date for the group project approaches, the focus of the whole module is on 'for' enterprise topics, and some lecture time is given over to group work. These session involve, therefore, the attending lecturer becoming a consultant from whom students can ask assistance where they have identified they need it. This is an effective method of encouraging practical skills development as students take responsibility and 'ownership' of their assignment as they would in the real world business environment.

Enterprise for Physicists is unique from other enterprise modules in that it is tailored entirely to physics: all teaching materials (case studies, examples, explanations of concepts, etc.) are physics based or oriented. As noted above, one of the main problems with delivery of business or enterprise education to engineering and science students is that they can be unaware of the relevance to them or their future career of these topics. Within the physics degrees at Heriot-Watt the idea that enterprise is not relevant to them is dispelled: students are made aware about the economic importance and value of physics and physicists to industrial competitiveness, and also of the value of knowledge about the economic status-quo, and the development of transferable employability skills for themselves.

7. Discussion/Conclusion

Due to both the uniqueness and newness of the approaches to delivering enterprise education at Heriot-Watt, an ongoing longitudinal research instrument has been developed, in collaboration with other Scottish universities, to assess impacts and measure effectiveness (see Galloway, et al., 2005). Feedback, particularly regarding attitudes to enterprise and entrepreneurship amongst science and engineering students, has provided a wealth of information and insight regarding the student experience, and results from engineering and science students on how enterprise education is impacting on ambitions and career intentions are promising (Galloway, et al., 2006). Science and engineering students who have experienced enterprise education generally perceive that enterprise skills have been developed, and demonstrate an understanding of the value of enterprise skills for use within existing organisations. This is very positive in terms of the potential for the application of these skills within whatever economic context students will eventually find themselves. Indeed, feedback from placement organisations and employers have reinforced that they 'like' students to have had exposure to enterprise teaching and an awareness of business operations.

Science and engineering students may have come to university without a clear idea for their future, or of the future possibilities, in their chosen discipline. They may well prefer dealing with mathematical problems and possibly even hate writing essays, reports and presenting arguments in 'words'. It might be difficult for science and engineering students to 'visualise' themselves in 'work' situations or as entrepreneurs, therefore, role models and relevant examples are very important. On some programmes, placements help contextualise learning for students and they grow in their knowledge and abilities. Guest presenters from relevant industries are also used in all programmes. In the case of the engineering institutions, steps are being taken to make students more aware of their own professional development and planning for it. At the university level, teaching staff at Heriot-Watt are committed to raising awareness of the 'real world'. Enterprise teaching in the curriculum helps students, who may not have grasped an understanding of enterprise, and to begin to appreciate the relevance of the economic realities.

Different disciplines have different requirements, educationally and professionally. Working with departments and key people or 'champions' has led to fruitful relationships and the development of teaching materials. For example, appropriate reading materials, good examples and cases of successful and unsuccessful entrepreneurs from the discipline afford enterprise teaching greater pertinence to students. There may well be entrepreneurial academics in the department who have developed new technologies or processes, launched companies or licensed their inventions. Role models help to contextualize learning and teaching and provide potential avenues for students to explore in their future. Making teaching materials appropriate for professional bodies is vital as, in many cases, graduating is just the first step and many other requirements have to be met in career development. Input from the enterprise team becomes part of the support for students as they discover new areas of learning and time for students' reflective learning is encouraged.

Embedding enterprise teaching in the curriculum is not something that happens overnight and it does take time, effort and patience. By providing specific solutions for disciplines, which often include contribution to 'professional development' or 'personal development' modules, the subject contribution can develop. Currently, input to Mathematics, under the personal development planning (PDP) approach is being established and plans are underway to contribute to Brewing Sciences also. Of greatest importance when deliberating over how best to provide enterprise education to a discipline is the ability to be flexible while maintaining pedagogical standards. At Heriot-Watt, flexibility is proffered for each embedding activity, and consultation with discipline staff promoted. This flexible, collaborative approach has been, most often, the key to the success of the embedding strategy.

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