UNIVERSITY AND INDUSTRIAL COLLABORATION: SOME EXPERIENCES OF PROJECTS INVOLVING BOTH STAFF AND STUDENTS AT THE UNIVERSITY OF SHEFFIELD, U.K.

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***Abstract**: There is considerable pressure from governments across Europe on universities to collaborate closely with industry to benefit EU economies, as the latter move from being manufacturing based to knowledge economies. The process is not an easy one: universities, traditionally, have not been involved in the commercialisation of their work and have policies of open publishing, rather than keeping research confidential. They also have a commitment to teaching and have to be involved in administering their institutions, so cannot just drop everything and focus on one project for a company, should the need arise. If these tensions can be resolved, however, there can be considerable benefits for both universities and companies, provided the projects are properly managed and planned so that academics and students are not placed in situations where strong conflicts of interest arise.*

This paper describes three ways of university/industry co-operation and includes two case studies: the first recounts how an academic became involved in a university company and the subsequent events and the second where a long running student training scheme involving industrial problems has benefited students, by giving them a practical dimension to their academic studies.

***Key words:** University/ industry collaboration, Student industrial training, University start-up companies, Innovation, Technology transfer, Intellectual property rights.*

INTRODUCTION

The move from Europe's economy being manufacturing based to knowledge based, has focused governments' attention on knowledge creation and innovation. Traditionally, the former has been a major role for university staff, whilst the latter has been the function of industry and the two have, often, proceeded independently.

There are now pressures on universities, across the EU, for industry and academia to work together (Lambert, 2003). These pressures will increase, not decrease, as China and India develop their manufacturing economies and Europe will have to rely on staying one jump ahead. Universities store knowledge, create knowledge and disseminate knowledge and are, therefore, seen by governments as having an important role in economic innovation - the ability to convert basic research into marketable products (Ashmore, 2006).

Whilst there can be benefits for both sides, there are also pitfalls. For successful co-operation, both sides must understand each other's roles and perspectives and work together to achieve successful partnerships (Collins, 2004). Academics are not business people and are involved in teaching and administration as well as research and so find it difficult to devote the time required, for example, to a start-up company. Often, a start-up company based on university research will demand continued support throughout the innovation process, as part of the business agreement, since it knows there is a need to convince customers of their expertise base and company executives might not fully understand the technology, although they are well able to exploit it. Start-up companies, however, are not the only way that industry and academia can co-operate. There are opportunities for consultancy and for undergraduate teaching.

This paper examines the experiences of the author in three types of university/industry co-operation to give an insight into the practical realities that face academics involved in innovation.

EXAMPLES OF UNIVERSITY/INDUSTRY COLLABORATION

Consultancy

Consultancy work is widespread throughout U.K. universities. It is under the control of the academic concerned and the amount of work is defined by an agreement. There is usually a daily rate of pay and the number of days is specified. The consultancy can be delivered through advice and discussion or written reports, but that is all defined within the agreement (or should be). The University of Sheffield helps it's academics with these agreements, by having a special office dealing with consultancy. When approached by a company to do work, the Consultancy Office will draw up a contract, describing the scope of the work to be done, the time and rates agreed and deals with other issues, such as who owns the IPR generated by the consultancy. Providing the academic goes through the Office with such a contract, the University provides Professional Indemnity Insurance against the possibility of claims for negligence. This is free for the academic until they earn more than £5000 per annum, when they then have to pay a 15% fee to the University. The money can be paid into salary, or into a departmental account. The former is the academic's personal money and as such is subject to income tax; the latter is free of tax, but the academic can only spend the money on professional activities within the university e.g. buy equipment, but not for any personal purposes. Generally the University is happy for it's staff to spend up to 35 days a year on such work. It is possible to do more, provided the Head of Department concerned is satisfied that other duties are not being neglected.

Bio-fouling and Corrosion Control Ltd.

This company, Bio-fouling and Corrosion Control (BFCC) was a university spin-off company, which was started by three academics at the University of Sheffield, U.K., from the Departments of Electronic and Electrical Engineering and Zoology. The author had been working in the area of electrical weed control and had noticed the adverse response of worms to the electric currents flowing in the soil. He read an article in a newspaper about the problems of marine bio-fouling found on the legs of oilrig platforms in the North Sea and he wondered if electric currents would displace them, as were the worms. He contacted the Department of Zoology and was put in contact with a colleague who was trying to see if the fouling in ship's seawater piping systems could be stopped by the application of magnetic fields. From this strange beginning a university company was formed, which was eventually sold to an oil company and whose products are now used world wide in the shipping and oil and gas industry.

After initial discussions, some laboratory experiments were undertaken, followed on by extensive trials at facilities on the west coast of the U.K. where there were plentiful supplies of seawater. The original idea of passing constant a.c. currents through seawater containing the microscopic larvae of mussels and barnacles was modified as time passed, to a system producing tiny amounts of chlorine and copper by electrolytic action from copper and platinised titanium electrodes. The copper and chlorine acted synergistically to prevent the larvae settling in the protected areas at concentration levels far below those required by using either copper or chlorine alone. When copper was used alone, concentrations of 20 - 50 ppb were required and chlorine systems usually dosed at levels of 1 - 3 ppm of chlorine. When used together, typical concentrations were 5 ppb of copper and 50 ppb of chlorine. At this stage, the university patented the idea and a university company was formed. The three original workers and a businessman owned 50% of the shares, with the university holding the other 50% and providing working capital (Williams et al., 1988; Knox-Holmes et al., 1988).

Some trial equipment was installed in the ships of the first customers, which was evaluated after several months to show that the system worked extremely well indeed. Fouling was eliminated or severely reduced in much of the seawater piping systems and in the boiler condenser tubing. The shipping company ordered more units as did other customers. It had been decided to try to enter the oil and gas industry and a unit was sold to an oilrig for evaluation. It was successful and, eventually, more units were ordered with extra staff employed to handle, control and store all the paperwork.

The university decided to sell the company to recover it's money to put into other projects and BFCC was sold to a Sheffield businessman, then he sold it onto an oil company three years later, where it was subsumed into their business and became one of their many products. Two of the original four went with the oil company, the author returned to the university and the businessman left for another job. Total sales to date of the equipment are probably in excess of £50m, with hundreds of systems being sold.

The involvement of an academic with a university company is very different from that of a consultant. The latter offers advice with a fixed time commitment of a few days, whereas an academic who is a director of a company is fully involved. The author was responsible for designing, building and commissioning the early test equipment then responsible for the equipment built under contract. There were visits to suppliers, customers, sales visits and service visits. Early systems were wired in-house, but latter ones completed under contract. On one occasion, the author arrived at the university at 08.00, delivered his lectures then was called at 12.00 to go to the dockyards at Marseilles, France. By 20.00 he was there and had to work throughout the night to sort out the mistakes made by a sub-contractor in the wiring of a system, before the ship sailed at midday the next day. There were the normal routine matters of running the company as well.

Although the university benefited and was very supportive, it made no time allowance for the company work and the author (and his academic colleagues) still had to deliver lectures, set and mark examinations and other assessments, attend laboratory and tutorial classes etc. and the author had to run the SHIPS scheme. What the academics could not do, with the workload, was further research nor could they publish the results of their early trials, since they were kept 'commercial in confidence'. Some papers were eventually written, but several years after the event.

Although the author enjoyed the experiences, they disrupted a normal academic career. In spite of being supported by the university, when it came to promotions then the committees were still concerned with publications and research output (increasingly so with the advent of the Research Assessment Exercise) and no publications - for whatever reason - was equated with no work! If universities are to encourage academics to become more closely involved with industry and commerce (and they will have to, right across Europe, due to mounting government pressures) then the commitment that involvement requires **must** be recognised. Many academic colleagues in the U.K. today do not want to be involved with the commercialisation of their work, in spite of the many opportunities, to the detriment of our economy; some because they are just not interested and just want to get on with their research, but others are not willing to give time in case they jeopardise their promotion prospects. The U.K. Research Assessment Exercise has had a distorting effect on the government's efforts to encourage closer links between universities and industry, as it only focuses upon research output and grant income, thus inhibiting commercialisation activities, and, in addition, tends to prevent inter-disciplinary collaboration, which is where really successful projects originate.

For a successful policy of industrial collaboration, it must be managed so that it is for the benefit of students and staff and not at their expense. If a colleague works on a commercial project then it must be recognised they cannot fulfil all their other roles and due allowance made for them to have the time to devote to the project. When they return to their normal role, then their achievements outside the university must be recognised within it, and due credit given, for promotion and status. The need for confidentiality and the resulting lack of publications should not be an inhibiting factor in an academic career. It is the role of senior management to ensure this happens and to maintain the balance between the usual work of the university and its creative activities.

There are several benefits for universities from being involved in start -up companies. Obvious ones are the income stream from royalty payments from IPR or earnings from share dividends or the sale of shares. This income can benefit individuals involved in the project, their departments and the university. There is also the credit that can be borrowed against that income for expanding general facilities within the university (an example of how effort in one department can be disseminated to the benefit of the entire institution). It is not just science or engineering departments that need be involved, although they are obvious candidates for innovative ideas in a technological society. For many years, the most successful venture in Sheffield was a publishing company established in the Department of Biblical Studies, publishing a variety of manuscripts and texts (Sheffield Academic Press).

Because of the concentration of intelligence, knowledge and academic ability, a university can be considered as a creative resource. If only a portion of that resource is focused on assisting industry and commerce, then the university can become a stimulus for economic growth within its region. By advising industry and participating in starting up companies, then it can help create jobs and facilities in the local area and thus become a focal point for regeneration as well as for education. Although the primary role of a university must remain as it ever was, the generation and dissemination of knowledge through research and teaching, the addition to its roles of promoting economic and social regeneration can add, not just to it's income, but also prestige to it's reputation and status.

SHIPS

The **SH**effield **I**ndustrial **P**roject **S**cheme, (SHIPS), was started by Dr. Russell Brown, in 1969 (Chambers and Brown, 1984; Diprose et al., 1997). It is for second year students as part of their three-year undergraduate course and originally took place in the Easter vacation. It was designed as an intensive 5, (which became 8) day course where students were presented with a real industrial problem and had to suggest possible solutions. A written and an oral report were given at the end. Due to the introduction of semesters, timetable restraints and increasing student numbers, the format has been changed in recent years so that it now takes place throughout the first semester of the second year. Although the intensive nature of the scheme has altered, the main structure and intent remains.

Prior to the event, the SHIPS tutor visited factories and businesses, large and small, to find projects for the students to tackle. Students were split into groups of about 6 of mixed ability and so about 15 projects were needed each year, as the scheme tried not to use the same project for more than one group, unless it was absolutely necessary. On the first day the student groups visited the host companies and were introduced to the problem by company engineers. They had a chance to ask questions before visiting the factory or plant to see the site of the problem for themselves. Later there was a tour of the whole plant so that students could see what a factory or production environment is like. For many of them it is the first time they have ever been into such a place and experienced the conditions under which many electronic systems function. After the tours, they returned to the engineers and completed their questions so they had as much information as possible to work with during the next few days.

The companies visited ranged from large steelworks (how can you tell if the lining of an arc furnace is worn thin?) to small steelworks (how can you tell when a ball mill has ground the ore away and needs re-charging?); shoe factories (how can you tell if the steel fastening for the heels on a ladies shoe are fixed properly?); airfields (how can you tell if fuel is leaking from the underground distribution system?); charities (how can you monitor the temperature inside a small, refrigerated medicines unit en-route to a disaster zone or epidemic?); museums (how can corrosion be detected inside an exhibit wing?); canning factories (how can the temperature inside a sealed can of food be measured to ensure it has been pasteurised properly?); chicken processing factories (how can you tell if a chicken is dead?) to finding ways of separating metal foil from wood chippings, for a company which wanted to use old tea chests for heating it's offices. Apart from all the physical restraints and the problem itself, students needed to know other factors e.g. how fast does the measurement need to be, or how much could the solution cost? Taking the shoe factory and the airfield as examples of two extremes, the former had fast running, mass production lines and so the test for each shoe had to take less than 0.5 sec and cost less than 0.1 EU cents, whereas the fuel leakage problem could take several hours to detect and the engineers said they could afford to spend up to 400,000 Euros on a solution; above that, they would have to ask someone!

The problems chosen needed to involve lateral thinking and, invariably, some form of measurement. What were avoided were problems such as: 'write a program for ....', or 'design a circuit to ......'. It must be remembered these are only second year students and whilst they can be very inventive and creative in their thinking, their detailed knowledge of programming and circuitry is small.

After the company visit, the students returned to the university and spent the next day brainstorming the problem. Members of staff assisted by offering guidance and by prompting the group if necessary, but did not give them a list of ideas. It was for the students to generate that. Then they reviewed the list and decided themselves on the best two or three ideas, split into groups and spent a few days following up their possible solutions and, if possible, made small demonstration models. On the final day, the companies visited the university and were given an oral presentation about their ideas for solutions and then this was followed some weeks later by a written report.

The present structure still involves the visit to the company at the beginning of Week 4 of the first semester of their second year, but instead of an intensive few days, the student groups meet at least one afternoon a week for the semester and presentation day is on Monday of Week 11. There are also 5 support lectures given in the period. Students now work with their tutor groups and receive help and advice from their tutors. It is generally felt that with the looser structure, progress and successful outcomes have declined since the days of the intensive course (Judd, 2006).

The benefits to the students are still considerable. They gain experience of a practical problem such as those they will have to solve when in work and the industrial environment. They participate in group-working and group-problem solving and practice their oral and written presentation skills.

They find out that life is not all about textbooks and get a chance to think about problems and apply some of what they have learned from their academic studies. There are two other benefits: they gain in self-confidence and it is an opportunity for the less gifted academically to move to the front of the group. Many times students complain at the beginning of the project that they know nothing about it and ask how on earth they can suggest anything useful? By the end, after realising that by working together, thinking across boundaries and following up ideas on the internet and in libraries and by asking questions and advice from academics they can achieve a great deal - often giving a company much to think about. In the groups it often happens that those students who do not perform well in exams, can lead a group or demonstrate excellent practical skills, whereas the 'bookish' who get all the high exam marks have to struggle to get to grips with hand-tools or practical thinking! For the weaker academic students it is a confidence booster as they can clearly see they have much to contribute.

The benefits to companies vary. It is not often that a company receives a direct, complete solution to it's problems - although it has happened occasionally. Generally, the students will confirm their own ideas and re-assure them they have not missed anything obvious. Sometimes the students can stimulate their own thinking and give them a new path to follow. With the student's suggestions and their own experience they can develop a possible way to success. Even the ideas the student's reject can be of help as one company realised, when they looked at the list of ideas that were brainstormed. The student group had chosen three methods from their list of ideas they thought applicable, but one the company saw in the reject list, coupled with some research going on in another of their factories, enabled them to devise a method to solve their problem.

The author only experienced one example in the several years he ran the scheme, where the students came up with a complete package. The problem was to find a way of telling when a ball mill was empty. This type of mill has small quantities of ore dropped in (e.g. 100 kg) and it rotates. As it does so, steel balls in the mill crush the ore to a powder and this falls through a suitably sized sieve. The process time varies between one fill and another and has its' maximum efficiency when the mill is about half full. The existing system had workmen stopping the mill every now and then, opening the door and looking in to see the level. Usually it had fallen below the best level. They then added sackfuls of ore - often overfilling it. Could the students devise a way of telling when the mill should be re-filled with a standard 50 kg sack to maintain maximum efficiency?

They came up with a method using a microphone and by listening to the sounds they could tell if the mill was full or empty. They even built a small working model linked to a computer, which had a very simple monitoring programme to indicate when it needed filling. They then went on to suggest that the whole system could be mechanised by feeding the stock through an Archimedes Screw controlled by the computer monitoring the ball mill. In addition, they told the company, the whole production rate could be linked with computers to orders and stock levels. The company visitors sat open-mouthed during the whole presentation. They had not conceived that these students, who had not seen any factory before, let alone theirs, could come up with such a complete plan. (With several modifications, and after about three years, many of the students' ideas had been implemented.)

There are many benefits to both companies and students, but the only possible conflict of interest the author is aware of, arises over the possibility of Intellectual Property Rights. Were the companies exploiting the students? The department felt they were not. It was only very rarely that the students had a direct answer; usually the companies had to spend a lot of time and effort following up the ideas, which were only presented to them, by the students, in a very elementary form. They also put a lot of time and effort into the scheme providing the projects and supporting the students. Even the ball mill project described previously, required three years of company effort and investment and no new concepts were developed - the equipment purchased was commercially available. There is also the fact that members of the university staff advise the groups and there are six members to a group. Who decides which of these actually made the critical suggestion? Does one member of the group appear on the patent or all? How important was staff input in generating ideas? There is also the question of responsibilities that accompany rights. If students want to benefit financially, if a company does, what happens if a company follows up their ideas and they do not work and it loses money? Will the students be liable to pay compensation? It was felt that the benefits to the whole student body were substantial and that since it would also be very difficult to actually assess the direct financial benefit to a company from the student's contribution, it would be best to allow companies to derive what benefits they could. The department and the university examined the legal aspects for this scheme and others run by the university and it was decided to introduce a clause into the university's registration documents where students agreed to waive their IPR rights when on departmental study projects, although it was not sure if it was legally enforceable.

In recent times, attitudes have changed and now the University has a standard agreement for IPR, which companies have to sign before offering projects. It keeps IPR with the University, but allows the companies to exploit it. This is generally accepted, although some companies have withdrawn after refusing to sign it.

CONCLUSIONS

There are various ways that academia can work closely with industry for mutual benefit. Universities are staffed with experts in many fields and there are opportunities for staff to use those skills to benefit companies and themselves through consultancy work. In addition it is possible to run student based, problem-solving, teaching schemes with industrial partners to the benefit of both.

When technology transfer is involved and research is commercialised, then the projects must be carefully planned and managed so that academics are not penalised or compromised by spending time on them. These can be very beneficial to universities and individual staff, by providing income streams from royalties, but the exploitation of IPR needs to be carefully done to avoid conflicts of interest between the need to publish and the need for confidentiality. With the correct procedures in place, universities can make substantial contributions to both the local and national economies and provide dynamic, knowledge driven leadership within their regions.

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