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A Short-Duration Industrial Project Scheme

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***Abstract*—The paper discusses the aims and implementation of a short-duration industrial project scheme run at the University of Sheffield for second-year undergraduates studying electronic and electrical engineering. Topics covered include the selection of suitable projects, the project briefing, the investigation of a problem, the project presentation, and report and project appraisal. The paper concludes with examples of specific problems which have been tackled and a look at the future of the scheme.**

I. Introduction

THE Department of Electronic and Electrical Engineering at the University of Sheffield, United Kingdom has traditionally offered three-year undergraduate courses which have a common first two years and only allow students to specialize in their final year. To complement these broadly-based courses, the Department has for many years involved its second-year students in a short-duration "think-tank" industrial project scheme (SHIPS)[1], with the broad aim of making both the students and the academic staff more aware of and, as far as possible, involved with current practice, techniques, and problems at the "output end" of industry. Although the scheme was conceived before the Finneston Report [1] and the United Kingdom Engineering Council's application modules EA1 and EA2 [2], it plays a major role in ensuring that our courses are accredited by the IEE and thus satisfy the educational requirements for professional engineer status in the United Kingdom.

During the seven days of a typical SHIPS project, students, while working in teams of six, are given

1) a chance to develop their problem-solving skills by exposing them in a controlled manner to a real industrial problem, with all its physical, financial, and possible environmental limitations and its accompanying high level of motivation

2) full scope to be creative and yet encouraged to be critical of their creations

3) experience of group organization and management.

4) experience in producing and presenting verbal and written technical information to a critical audience.

From the industrial viewpoint the motives for collaboration in SHIPS may be summarized as

1) the prospect of obtaining a new solution to a problem or, at the very least, confirmation of an existing situation

2) the fostering of university liaison by making contact on a personal working basis, but without involving too much effort or financial expenditure

3) to help with the education and training of engineering students

4) to try to attract high-quality engineering graduates to the company.

From the onset of SHIPS it was recognized that potential problems arising from confidentiality and patent rights might prevent companies from collaborating whole-heartedly in the scheme. Accordingly, projects are solicited on the basis that confidentiality will be respected and that all patent rights will be waived by the University participants. In the event, since few proposed solutions in their original form have yet proved patentable, the potential loss of such rights has been more than outweighed by the other benefits gained by students and staff from collaborating with the companies involved.

II. Implementation

A. Selection of Projects

The problems to be tackled are sought from industry by the author who has the dual role within the Department of full-time academic and part-time Industrial Liaison Officer (ILO). Although no restriction is placed on the type or size of company that might be approached for projects, the limitation of having to be able to visit a company within one day means that only those within a radius of about 150 miles from Sheffield are considered. Furthermore, because of the limited funds available for student visits, another criterion based loosely on the product of the number of projects offered by a company and its proximity to Sheffield is also applied.

Collaborating companies are specifically requested not to "tailor" problems in any way and, in order to broaden the experience of both students and staff, *there is generally no restriction on the areas of engineering from which problems are sought*. Hence, over the years, projects have been tackled in the diverse fields of aeronautical, agricultural, chemical, civil, mechanical, metallurgical, nuclear, process, telecommunication, and value engineering. For a given problem to be tackled "successfully" by a project team, it must be chosen with care. Undergraduates towards the end of the second year of their course do not have in-depth, specialist knowledge; hence, it would be pointless, for example, to ask them to investigate the detailed design of a particular, very specialized electronic circuit or system. Such an exercise is best left to the expert in the company. On the other hand, a problem which

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[1]The Sheffield Industrial Project Scheme.

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demands a broader knowledge at a lower level, and, hence, one which might be tackled by lateral thinking, is much more suitable. In practice it has been found that measurement or instrumentation problems are the best ones to tackle. Even with this type, however, a problem must be sufficiently tangible for the students to feel that they can make a start in tackling it.

B. Project Briefing

Before visiting a company to be briefed in depth about their project, students are given only a broad outline of the way in which the scheme is run and are allocated at random to a particular project and project team. The aim is thus to mix up groupings or cliques of students which may have formed due to common interests or formal laboratory classes. By keeping project teams in relative ignorance of their specific projects at this stage, they are forced to retain open minds, which is an essential ingredient of the later brainstorming sessions. To prepare them for the latter, the teams are given a list of general references which have been found useful in the past [3]-[6]. As well as discussing the concepts and strategies of brainstorming and problem solving, some of these contain extensive but by no means exhaustive lists of physical laws and effects which might be applicable to the solution of any particular measurement problem.

From the time of this initial, previsit briefing until the submission of the final version of their written report, students are urged to think and work as part of a team. The organization of the latter is usually established on a concensus basis, and personality clashes within a team are not considered an excuse for altering its composition.

On the first day of the scheme, while traveling by bus to visit a company, teams are urged to prepare a list of possible questions which they might wish to ask during their visit. It is stressed that while at the company, teams must make the maximum use of their time with the company's engineers to extract information in order to understand the nature of the problem they are being asked to investigate. On the return journey, information provided by the company can be studied, notes made about the visit, and initial impressions pondered upon.

Each project team is accompanied during the visit by at least one member of the academic staff who receives exactly the same briefing as the students. Care is taken, however, to ensure that all staff visiting a particular company are briefed on all the projects associated with it. In this way, during the later stages of the scheme, a project team will always have access to at least one member of staff who is conversant with their particular problem. The other roles of the staff during a company visit are, first, to ensure as far as possible that difficulties arising from inadequacies in a project briefing or works tour are avoided, and, second, to act as a surrogate for the ILO in making arrangements with company personnel for their visit to the Department on the last day of the project period for the project presentations.

C. The Problem Investigation

Following the visit to the company, project teams spend approximately five days in the Department at Sheffield investigating their assigned problem. This period of time is divided between three main activities:

1) brainstorming, to arrive at a number of possible solutions (1 day)

2) elimination of those solutions which do not appear to be feasible due to natural or company-imposed constraints (1 day)

3) gathering information about the usually small number of most promising solutions and carrying out first-order confirmatory experiments utilizing whatever samples and equipment are readily to hand not only within the Department but also elsewhere in the University (3 days).

The durations given above for each phase of the investigation are only approximate and vary from one project to another.

D. Project Presentation and Report

The penultimate day of the scheme is spent in planning the verbal presentation to the company's personnel and the layout of the written report. Since all members of a team contribute to both, individual responsibilities for particular sections are allocated at this stage with one member acting as coordinator and report editor. As this will probably be the first time that many of the students will have had to make a formal technical presentation of this kind, the importance of rehearsal and the use of clear, unambiguous diagrams is stressed. To save effort, teams are advised to prepare artwork for diagrams in such a form that it will be suitable not only for the making of OHP transparencies, but also for illustrating the written report which follows the verbal one.

In the early days of the scheme the verbal presentations were given at the company but now it is seen as preferable for the company's personnel to visit the Department instead so that they can also see something of its research work and facilities.

E. Project Appraisal

No formal attempt is made to assess the performance of individuals in the SHIPS scheme. Throughout students are encouraged to work together as a team; hence, the end product is a joint effort which is appraised as such. By having regular progress meetings with the academic staff throughout the project period, students are encouraged to appraise themselves not only in terms of the progress made so far, but also in considering the best way of directing the team's effort so as to meet the project deadline.

The concept of group self-appraisal is carried through into the verbal and written report stages of the scheme as well. During the verbal presentation and the ensuing discussion with company personnel, both sides are encouraged to be critical of the proffered solutions to the problem under investigation, but care is taken to temper such criticisms so as not to submerge the positive aspects of the team's efforts. In some ways this corporate appraisal by the students and the company personnel may be likened to the outcome of a football match, i.e., it can be described roughly in terms of a win, a draw, or a defeat. In practice, most teams score a draw, i.e., their preferred solution agrees closely with the company's present or proposed solution. This is not surprising given the nature of many of the problems that are tackled such as those of the "old chestnut" variety or those waiting for a solution to be based on new technology. Nevertheless, the range of ideas and techniques examined by the students is often much larger than that examined previously by the company so that the latter can be confident that any potential loop holes have been reduced or eliminated. In a small number of cases, project teams score a win, i.e., their ideas are both genuinely new to the company and are promising enough to warrant further investigation.

When the projects are written up, team members are again encouraged to appraise each other's work and this appraisal is coordinated by the student editor, who, with the assistance of the staff editor, ensures that the report is worthy of submission to the company under the auspices of the University.

F. Administration

Because of the inevitable pressure of work during term time, it has been found convenient to run SHIPS once each year during the Easter vacation. Then, all second-year students and all academic staff within the Department are fully committed for seven days; a "day" quite often lasting from 7 a.m. until 10 p.m. The impetus of the work is maintained by ensuring that the collaboration between students and staff is extremely close. For example, meals are taken together in a central location and heavily subsidized to ensure that they are working occasions. Hence, even though the project investigation is of short duration, the pressure on the participants and, hence, the pace of work is much higher than is normal in an academic environment, and the actual effort devoted to each problem is at least 450 man-hours, excluding the time devoted to producing a final report.

The SHIPS program is funded from a special university budget for vacation training. The cost per student, including expenses involved in setting up the projects with industry is surprisingly low, typically $50. The cost to a company participating in SHIPS is also minimal, since company personnel take part mainly on the first and last days of the program. Normally the cost to the Department of providing components and equipment for confirmatory experiments is also very small since participating companies are expected to provide samples or jigs if these are available. If not, then other companies which have previously been involved with SHIPS or other departments within the University will often provide items on short-term loan.

III. Examples of Projects

The SHIPS program has now been running for almost 20 years, and during this time over 180 projects, suggested by about 70 companies, have been tackled. The typical examples listed below serve to show the diversity of problems that industry have suggested to us:

1) measurement of the specific gravity of two highly radioactive liquids flowing one above the other in a channel,

2) measurement of the eccentricity of hollow ball bearings,

3) methods of attracting the attention of motorists on a motorway,

4) detection of the edges of crops and cultivated soils,

5) methods of measuring the amount of edible oil on the surfaces of a winegum,

6) detection of partially filled cans on a production line,

7) measurement of the velocity variation of a spirally-wound cardboard tube on a forming mandrel,

8) methods of transmitting high-speed digital data through a metal plate,

9) automatic refuelling of automobiles.

Before exposure to SHIPS, electronics students towards the end of the second year of their course see little need to have a basic grounding in, for example, mechanical engineering. However, after being given a problem such as 1) listed above, where an electrical solution may be very expensive or impossible because of the high level of radioactivity involved and the paramount need for long-term reliability, they rapidly appreciate the merits of solutions based on "strings going over pulleys."

Problem 2) also illustrated to the students that "simplest is often best." It arose from the aerospace industry, where it was proposed to save weight in jet engines by incorporating hollow balls in the bearing assemblies. After trying a number of possible electrical solutions with inconclusive results, the students performed the elementary experiment of rolling the balls down an inclined plane. A ball whose internal cavity was concentric with the outer surface rolled true, whereas an "eccentric" ball took a cycloidal path. This "wobble" could then be detected electronically and the ball rejected.

Problems such as those listed under 3) and 4) give students an insight into dealing with random processes (e.g., nature) and, perhaps more importantly, make them realize that the real problem to be solved is often not that originally posed. For example, problem 4) has received much previous attention, with tractor guidance schemes based on buried cables and optical beams being proposed and rejected on adverse economic, terrain, and meteorological factors. The students' preferred solutions to this problem were based on furrow following or standard aircraft radio navigation techniques and some initial experiments on the latter were modeled in the laboratory using standard microwave equipment.

Even when it may be clear from the outset that an electrical solution to the problem may be forthcoming, examples 5) to 8) still require extra knowledge in these cases of physics, chemistry, and materials to ensure that a correct choice of measurement parameter and, hence, transducer type is made. The students found problem 8) an especially challenging one which required transmission of a 10 MHz digital data stream through a metal plate some 10 mm thick. After much brainstorming and experimentation, it was decided that there was no solution to the problem as originally posed and that either the data rate requirement would have to be relaxed or else a window with stringent pressure and optical properties would need to be set into the metal plate. In the event, the latter solution was the one accepted by the company involved with the project.

Finally, problems such as 9) may need to take into account not only the subtleties of robotics but also the vagaries of the consumer. In this case, the problem investigation was confined to a paper study because of the lack, at that time, of suitable robotic equipment in the Department, but one can envisage the students performing such experiments as determining the best way of locating a filler cap on cars which may come in a variety of shape and sizes. This might then lead to recommendations for a standard design of filler cap suitable for robotic manipulation.

Although this discussion of typical projects has necessarily been brief because of considerations of commercial confidentiality, it is hoped that it has conveyed some flavor of the type of problem which has been found to offer a wide ranging challenge to the students (and also the academic staff!)

IV. Discussion

From the favorable comments made by participating companies over the years there is no doubt that in industry's opinion the SHIPS scheme is seen as being worthwhile. This view is reinforced by the significant number of companies who have participated more than once in the scheme and the fact that on occasion unsolicited offers of projects have been made by companies subsequent to their initial involvement. Industrial staff have almost invariably been surprised by the high standard of the solutions proposed to their problems and the predominant reason for companies ceasing to collaborate is an apparent lack of suitable new problems. In some instances close links have been formed between the Department and companies whose main activities are quite unconnected with electrical engineering; thus, new avenues of research and consultancy have been opened for academic staff leading to a broadening of their interests and expertise.

As well as improving its relations with industry through collaboration in SHIPS, the Department has benefited through the vastly improved personal relationships between the academic staff and the students arising from them working together in close-knit teams. This has also been helped by a program of social and sporting interaction which is seen as an essential part of the project scheme.

Immediately after exposure to SHIPS, students are generally very enthusiastic and convinced of its value. In time, however, this euphoria fades and they become more critical; yet very few have been prepared to state that the scheme should be abandoned. The most common criticism is probably that the direct involvement with industry was less than they would have wished.

In the final year of their course, soon after exposure in the SHIPS program to the techniques of problem solving and project management, all students undertake an individual research project of ten man weeks duration (actually spread over 20 weeks). There seems to be no doubt that prior exposure to SHIPS enables the students to achieve better and more consistent progress with their research and perhaps, most importantly, to communicate the results of their findings to their colleagues and assessors.

As to future development of SHIPS, the scheme is being expanded so as to incorporate mixed project teams containing students from both the Department of Electronic and Electrical Engineering and the Department of Control Engineering. Such an enhanced SHIPS scheme has certain attractions from an educational viewpoint but there may well be problems in administering such a large exercise (with around 130 students and 22 projects) with only part-time ILO's in both departments. Another proposal, relevant to the proposed four year course[2] in the Department of Electronic and Electrical Engineering at Sheffield is that the small number of students who would be selected to embark on such an enhanced course might take one or two of the most promising solutions proposed each year in the present SHIPS scheme and collaborate with the companies, again as a team effort, in carrying out a proper feasibility prototype development project lasting up to six months.

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[2]Such a course would lead directly to the award of a Master's degree rather than the Bachelor's degree normally awarded after a three-year course.

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