Int. J. Engng Ed. Vol. 19, No. 5, pp. 712–716, 2003
Printed in Great Britain.

0949-149X/91 $3.00+0.00

Students as Tutors—Learning Problem-Solving Skills by Tutoring PBL*

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This paper commences by briefly introducing the Systems Engineering degree programme at Loughborough University, explaining why it was designed with problem-based learning (PBL) as its integrating theme. The paper focuses on a final-year module which requires finalists to act as tutors to second- and first-year students undertaking PBL-based group project work. It explains the rationale for this approach and discusses some of the lessons that have been learned from the process. The paper concludes by discussing the benefits to the students of this form of facilitating and mentoring PBL.

INTRODUCTION

THE CONVENTIONAL APPROACH to teaching at the university degree level presents lecturers as experts passing on their specialist knowledge. A 'chalk and talk' method or, better still, a 'web-based student-centred learning' approach, where the staff provide the knowledge in palatable units and then assess the success of the students in acquiring that knowledge, permits large numbers of students to be taught by a single teacher. This appears to be an extremely cost-effective method, where more students can be taught by fewer staff, thus allowing the university to remain financially sound. Most universities in the UK have adopted this approach as the preferred method of teaching. The combined lure of the use of 'leading-edge' technology and the apparent cost savings render any argument about the educational advantages of alternative approaches ineffectual. The suggestion that problem-based learning is a more effective way of developing professional skills [1] and competencies amongst students [2], if considered at all, is habitually met with objections that the costs are higher because more staff are required to teach the same content, it takes longer to teach the same material [3] and it is not suitable for web-based distance learning, which is where the future is perceived to be.

Nevertheless, despite such pressures, Loughborough University designed and introduced a very successful Systems Engineering degree programme, which has run since 1992 and has PBL at its heart. This paper commences by briefly explaining how this happened. The paper then introduces an 'experiment' in developing the systems engineering skills of the final-year students by having them act as tutors for second- and first-year students working in groups undertaking PBL-based project work. The process adopted is explained and some of the issues raised by the final-year students are discussed. Finally, the perceived effects on the learning outcomes of the choice of first-year problem is discussed.

PBL AS THE FOCUS FOR THE SYSTEMS ENGINEERING COURSE

The Systems Engineering course was created when the university was asked by a major engineering firm to provide a degree which would produce 'systems engineers' who were generalists, capable of forming the glue in teams of specialists and providing problem-solving skills. The vision was of students who would be proficient in three engineering disciplines (electrical and electronic, mechanical and aeronautical), plus computer science and human factors. The university accepted the commission and formed a degree programme which would be spread over five years. Academic work in the first and last two years was complemented by industrial placements during two summer vacations and the whole of the third year.

Although the company wanted a new degree, the university wished to reuse existing specialist modules wherever possible, to retain academic credibility and save costs. However, there was a need for a systems engineering spine within the course which would assist the students to develop the necessary skills. It was, therefore, necessary to find ways of teaching this material that would motivate and enthuse the students and enable them to make sense of the multidisciplinary material that they would be taught. Problem-based learning appeared to be the ideal means of accomplishing this objective [1, 4]. It was recognised that there would be difficulties in adopting this method, but several of the individual lecturers involved in the design were enthusiastic about PBL and were prepared to put extra time into the course.

* Accepted 25 August 2003.

The initial design of the course provided for specialist 'systems' modules comprising one sixth of the total teaching time in the first three academic years, with the remainder of the time being spent on material drawn from the various specialist subjects. The whole of the final year was devoted to providing the students with specialist expertise in one subject. The systems modules in the first two years used conventional teaching methods with associated examinations to cover the systems process and some mathematical and engineering design techniques. The main bulk of the systems 'teaching' was, however, focused on problem-based learning, with different scenarios and different aims and planned outcomes in each year. This was based on the constructivist approach to learning, where the learner is expected to construct personal meaning by engaging in dialogue and reflection [5, 6].

The first-year systems module included three assessed projects where the students worked in groups of five or six (different groups for each project) to consider aspects of large-scale, complex, multidisciplinary systems. The groups were expected to meet in a project work area for three, four and six afternoons respectively, to research the presenting problem and discuss the issues amongst themselves and with the systems support staff, and then deliver a 10- to 15-minute presentation and a short report on what they had found. The second-year students were given five mini-projects to undertake in self-selected groups of five or six, with only the last one being assessed. In the third year, self-selected teams of five or six bid for year-long projects which involve the design and development of some engineering 'product' (e.g. a pregnant crash test dummy; a portable law and order support device).

Developing and improving presentation skills is an important objective for all three years, as are providing appropriate written reports and reflecting on the performance of the group and on the contribution of individuals to the group. Other common objectives are to help the students to understand the complexity of real systems, the difficulty of eliciting requirements and assumptions and the need to work in a group because no individual will have either all of the required skills or the time. However, each year also has its own objectives and the balance of the common objectives varies. The projects in the first year were intended to help the cohort to mix together and get to know one another and also to recognise that real complex problems are not easily delineated, or understood, and that different people can legitimately hold quite different views about what is important and how the problem might be approached. The second year is primarily focused on exploring different forms of presentation and on learning to spend an appropriate time on tasks. The third year provides the first opportunity for the students to undertake a complete project from start to finish which involves them in collecting the requirements, scoping the task, liaising with two different and conflicting clients and managing their time. The two clients are their technical supervisor, who, typically, is expecting them to 'get on with the work' and the systems team, who require the group to show that they are using a valid and sensible systems approach. Fifty percent of the marks for the module are given for each aspect, with the systems mark being subdivided between group reports, a 30-minute presentation and a 30-minute demonstration.

In addition to the specific problems which the students were asked to address in the systems modules, they were told that the biggest problem they faced was of supporting one another through the programme and integrating the material they would be given to provide the systems perspective.

The first cohort of students graduated in 1997, with the majority joining the sponsoring company nominally as 'systems engineers' but practically as subject specialists because of the existing team structures. By 1999, when two more cohorts had graduated, it became clear that there was a real need for the addition of some systems 'teaching' in the final year, which would reinforce the systems lessons they had learned in the first three years and help the students to be able to deploy their systems skills for the benefit of the companies for whom they worked. The module that was introduced in the final year and its relationship to the first two years' systems teaching forms the focus for the following section of this paper.

APPLYING SYSTEMS THEORY

The course had successfully enabled students to gain sufficient academic knowledge to be able to work in specialist teams and sufficient problem-solving skills to enable them to complete the course and please their employers. They had also performed very well academically, not just in the systems modules, but also in the modules taken by single-subject specialists, where, in several cases, the systems engineering students had outperformed the specialists students on average [7]. However, apart from assisting one another, they had had relatively little experience of facilitation (i.e. of encouraging groups working on projects to achieve their potential). In the initial design of the course this appeared to be a relatively unimportant and possibly unachievable objective. Nevertheless, once the other objectives had been achieved, it took on greater importance. Furthermore, it appeared to be a further opportunity to use a PBL, or 'learning through doing', strategy. Getting final-year students to work with first- and second-year groups undertaking PBL projects would give them an ideal opportunity to try out their facilitation skills in a supportive environment. The benefit to the younger students was also seen as being significant. There would be more tutors to support them through their PBL tasks and these would be people who, unlike the existing staff, had already experienced the process that the students were being put through.

The format of the module was for the finalists to be given an initial class-based reminder of what was expected from facilitators [8] and then for them to be assigned in teams of three students to second-year groups undertaking a mini-project. The finalist teams would be changed for each mini-project and different teams would be assigned to a second-year group each time. Each finalist consults with two different second-year groups, is required to attend the meetings of the group and to report back using a web-based reporting system on the progress of the group and the contributions being made by the individuals in it. Feedback is provided to all of the finalists, both on their reports and on the comments of the second-year groups. They are then asked to act as consultants to a first-year group undertaking their third systems project. The finalists are also required to attend the presentations given by the first-year groups at the end of their project and to provide an assessment of the performance of the groups. The consultancy is carried out in teams, but each finalist is expected to produce and justify their own reports and assessments. They are also required to produce a final individual report which reflects on the consultancy process as a whole. The task of the finalists is to help the second and first years think about the problems they are posed in different ways. The finalists should not tell the others what to do; suggestions can be made but the solution must be owned by the second- or first-year group.

REFLECTION ON THE MODULE BY STAFF AND STUDENTS

The initial reaction from many of the finalists to being told what they would have to do was that the module was relatively straightforward and unchallenging. However, by the end of the module most of the students had revised their opinions and several have subsequently commented on the value it had, both in providing an advantage at interviews and as a good preparation for working with and in teams in the workplace.

One interesting observation in the initial reports by the finalists was the difference in attitude that was evident on crossing the line from student to consultant. Quite a few of the finalists expressed outrage at the unprofessional and uncommitted attitude of the younger groups, citing behaviour that had been typical of their own performances when they were in the first or second years. Initially, the staff perceived this as irony, but it soon became apparent that the finalists appeared to believe what they were saying and needed to be reminded of the process of learning and maturing. A second observation was the increasing thoroughness of the reports as the module progressed. Many of the reports on the meetings with the first group were brief and lacked thought, but, when the students were reminded of the fact that the reports contributed marks to their degree classification, the reports became more professional and much more thoughtful. The final reflective reports were of a high standard and included several ideas and comments that had not previously been fully considered by the staff.

One particular focus of the reports was on the effect of the choice of problem on the learning objectives. This was made possible because the finalists had themselves undertaken a different type of project when they were in the first year and could compare their experiences with those of the students they were 'supervising'.

The first-year students who were being supervised had been asked to study an engineering system that had failed and report on the causes of the disaster and the prevention of similar disasters in the future. By contrast, the final-year students had been given a fun project ('Design a New Fairground Ride') when they were the first-year students. However, in both cases, the students were asked to tackle the task from a systems perspective.

The chosen disaster topics included: the Concorde crash in France, the Chernobil nuclear disaster, the Kegworth aeroplane crash, the Piper Alpha platform fire, the Kirks submarine and a tanker oil spillage, as well as less-known disasters. These problems were interesting, real and challenging and cannot readily be explained using the technical material they had learned in other conventional modules. The students were expected to take responsibility for discovering the events that had led to the disaster and reflecting on the lessons to be learned by searching articles, reports, TV programmes and other printed and on-line resources. As part of this process, they also need to become conversant with the technical issues and jargon by reading the relevant engineering and scientific books and journals. The finalists had also had to learn about some of the issues, such as safety, but had had much more freedom in directing their work along lines that they were interested in and could enjoy.

The final-year students felt that, although the systems engineering skills they learned through the process were intended to be the same, a serious problem such as a disaster and a fun project such as a fairground create different learning environments with distinct PBL differences:

- First of all, they felt that the disaster project highlights the importance of the systems engineering approach in a clearer way. Since the disaster had actually happened, the events and social implications were already verified and the interactions, or consequences of the lack of them, would be easier to identify. This helped the students to develop a better systems engineering approach.

- Secondly, because collating the evidence in a disaster problem was much more difficult than working on a fun problem, the students could understand how difficult it was to work with missing information and assumptions. The problems of reading lengthy reports and the consequent misunderstandings that occurred were additional areas that could be learned from.
- The students took the disaster project very seriously and tried to design generic systems solutions to prevent such events happening again and hence to do something useful for humanity. On the other hand, having a fun project provided a relaxed atmosphere and created a very friendly environment. There was space for humour, fun and jokes. This bonded the students and led to better friendships and hence collaboration, dedication and better team work. Finally, a fun project fuelled enthusiasm and creativity [9]. More excitement for learning and dedication to the subject were also noted. These were reflected in the presentations.

CONCLUSIONS

This paper has endeavoured to show that PBL has been highly effective in providing the basis for the development of systems engineers, even though very few of the staff had had experience of PBL prior to its use in the systems modules. The particular advantages of using PBL as a means of encouraging facilitation skills have been highlighted and some of the more interesting observations on the process from the final-year students have been presented.

The 'Applying Systems Theory' module was added to the programme to reinforce the systems lessons that the final-year students learned in the first three years and to help the students to gain confidence in deploying their systems skills. The integration of final-year students into the tutoring process also added freshness to the experiences of the first- and second-year students. Furthermore, there were more tutors to support the first and second years through their projects and the support was from people who had already experienced the process.

The systems engineering course can be regarded as a success for PBL. It is worth noting that there are still the general constraints PBL places on teaching within the organisation. However, the client company has been delighted with the product (the graduates) and the academic results have been excellent in all subjects, a result which can be attributed to the effective use of PBL.

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