Changing Structures for Delivery - Breaking Traditional Barriers

CHANGING STRUCTURES FOR DELIVERY – BREAKING TRADITIONAL BARRIERS

Barry Lennox[1], Bill Crowther[2], Beverley Hopping[3], Rachel Tobbell[4] and Norman Wood[5]

Abstract - *In September 2001, the School of Engineering at the University of Manchester adopted problem-based learning as the primary teaching method for its undergraduate programmes. This paper describes the structure of the new course, provides examples of the problems that the students have been tackling and also gives some observations that have been made following the successful completion of the first year of this course.*
Index Terms - Problem Based Learning, Engineering

INTRODUCTION

It was recognised for a number of years that there was a need to conduct a thorough review of the content and delivery of the engineering programmes offered by the University of Manchester. The necessity to review the programmes was driven by two principal factors. The first is that the changing nature of 6th form education means that school leavers are increasingly mismatched with the traditional requirements of undergraduate engineering programmes, particularly in mathematics. The second factor reflects the changing needs of industry, who look for graduate students who not only possess a solid understanding of the fundamental science of engineering, but also have a practical and confident approach to problem solving, can function well in a team and have excellent communication skills.

To address these factors, the decision was made in 1998 that the Manchester School of Engineering (MSE) would create a series of new undergraduate engineering programmes that would adopt a problem-based learning (PBL) approach to teaching and learning. PBL represents a radical change to traditional teaching methods, particularly in engineering, where programmes throughout the world rely heavily on formal lecture course.

PBL was developed at Cape Western Reserve University Medical School in the USA in the 1950s, however, it was McMaster University Medical School in the 1960s that established PBL as a suitable method of learning in higher education. Based upon the original model of McMaster, PBL has been introduced in higher education establishments throughout the world. Although its application has primarily been restricted to medical schools, where it is estimated that in the USA over 80% of schools have adopted PBL in one form or another [1], there are examples of its use in health sciences, nursing, dentistry, pharmacy, veterinary medicine, architecture, computing and engineering.

This paper describes how PBL has been integrated within the engineering programmes in the Manchester School of Engineering (MSE) at the University of Manchester. The paper begins by providing a brief overview of the programmes that are offered in MSE. This is followed by a description of PBL and in particular, the method which has been adopted at MSE. Details of how PBL has been integrated within the engineering programmes at MSE is then provided along with observations that have been following the successful completion of the first year of the programmes. The paper concludes with a series of modifications that are to be made to the programme and a series of conclusions relating to the programmes.

STRUCTURE OF THE ENGINEERING PROGRAMMES IN MSE

Overview

MSE offers a total of 27 undergraduate degree programmes. These programmes are based around 5 core engineering disciplines, which are Mechanical Engineering, Aerospace Engineering, Avionics and Aerospace Systems, Energy Systems and Engineering Design, Simulation and Modelling. The first year of all 27 programmes is common to all students, whilst in the second year the students split into two streams, Mechanical and Aerospace, and in years 3 and 4 the disciplines divide completely into the five programme areas.

PROBLEM BASED LEARNING

Motivation

The first stage in developing the structure for the new engineering programmes at MSE was to determine the aims and objectives for them. These aims and objectives were guided by consultation with industry, students, engineering institutes and benchmarking documents. After completion of

[1] Barry Lennox, School of Engineering, University of Manchester, Manchester, UK. Barry.Lennox@man.ac.uk
[2] Bill Crowther, School of Engineering, University of Manchester, Manchester, UK. W.J.Crowther@man.ac.uk
[3] Beverley Hopping, School of Engineering, University of Manchester, Manchester, UK. Beverley.J.Hopping@man.ac.uk
[4] Rachel Tobbell, School of Engineering, University of Manchester, Manchester, UK
[5] Norman Wood, School of Engineering, University of Manchester, Manchester, UK. N.J.Wood@man.ac.uk

the aims and objectives for the programmes it became clear that it would not be possible for them to be achieved through a formal lecture based approach and that it was more appropriate to introduce PBL into the programmes.

Problem Based Learning at MSE

The basic approach to PBL that has been adopted at MSE is a slight variation on the model introduced at McMaster University [2]. The variations were introduced when the PBL material was tested on groups of school leavers and undergraduate students.

Within each PBL activity, the duration of which is 1-2 weeks, groups of up to eight students work through a given problem. Figure 1 provides an example of a problem that the students are provided with. This particular problem focuses on the study of statics and dynamics in year 1 of the programme and lasts for 2-weeks. This problem, as with all of the others, took many months to develop. The procedure for developing the problems was to begin by identifying the learning outcomes of the activity and to then develop a problem scenario that would lead to the students meeting these outcomes. Before the problems were introduced into the programme they were tested at length using groups of school leavers and undergraduate students. This testing phase proved invaluable as the students would often focus on unexpected aspects of the problem which, from an engineering perspective, were irrelevant. For example, in the problem scenario provided in figure 1, the students initially focused on acts of vandalism. As a consequence, the second paragraph was altered to eliminate this aspect.

In working through the problems, the students are encouraged to follow a set procedure that involves the recalling of knowledge, formulation of questions, discussion of what has been learnt and finally reflection. Further information regarding this can be found in [3].

The PBL groups are each assigned a base-room, where they can complete their work, and they are monitored by an academic facilitator whose role it is to guide the group towards achieving the intended learning outcomes for the problem. The students attend facilitated meetings a minimum of three times a week, but the timetable also incorporates expert forums, and workshop sessions, which provide extra guidance. During meetings, the students present the findings of their research to the rest of the group and pool their knowledge. Here they take on the role of teaching one another, helping colleagues and at the same time reinforcing their own learning. Everybody is under pressure to contribute since the students are mutually dependent on each other’s information. This approach requires students to plan, and reach agreement through negotiation and self-discipline.

Continual self-evaluation is encouraged, and the students keep a reflective log known as a learning journal as part of their Personal and Academic Development Plan (PADP). For the duration of the PBL exercise, the student keeps a record of his/her own notes, teaching materials received from other group members, and a reflective commentary on his/her own progress. This commentary includes personal skills acquired through team working and may also include the roles played by individuals in the group, how well the group stuck to the task, time management, and how the group resolved differences.

Assessment is managed using a range of group and individual tasks. These include a multiple choice test, presentations, web page design, report writing and demonstrations. The students Personal and Academic Development Plans form part of the assessment as a record of process, reflection and peer assessment, and of the knowledge acquired during the PBL period and the application of that knowledge. Feedback is given by the facilitators and also by the problem designer. The PADP’s are submitted for marking at the end of every PBL activity and returned with comments before the next activity commences.

STRUCTURE OF THE MSE PROGRAMMES

This section describes the structure of each of the years in the undergraduate degree programmes.

Year 1

The theme of year 1 is *learning to learn*, which reflects an important aim of the new programmes, which is to instil in the students the desire, motivation and skills to think for themselves. To achieve this aim year 1 contains a balanced provision of design, PBL and skill training.

The initial plan for year 1 was that PBL would be used as the only method of delivery of course material. Unfortunately it quickly became apparent that this would not be suitable as there was insufficient time available in the year for the students to complete the necessary number of problems that would ensure that the first year syllabus was covered. It was therefore decided that year 1 would be split between PBL activities and taught courses. The PBL activities would cover the majority of the core engineering science with the taught courses providing theoretical underpinning and filling in any gaps in the syllabus not covered in the PBL activities. A further benefit of the taught courses was that they provided some risk limitation for students and staff. Although PBL has been implemented in engineering programmes elsewhere in the world, the scale of its integration in the programmes offered by MSE far exceeds any of these implementations. There was therefore the concern that on such a large scale, PBL would be unsuitable in an engineering programme, thankfully this was found not to be the case.

The timetable for year 1 is provided in figure 2. The basic philosophy to the timetable is that the year is divided into two-week blocks. Each of these two-week blocks featuring either PBL activities or taught courses. The exception to this is at the beginning of the year when the students complete five 1-week PBL activities. The purpose of these activities is to practice group working, learn about PBL and discover how to get the most out of it.

During the taught course weeks, each day of the week is assigned to a different engineering topic. The five topics being Thermodynamics, Statics and Dynamics, Mathematics, Design and the Professional Engineer. Each of these days takes a tutorial style format and includes brief lectures, of no more than 15 minutes, followed by problem solving sessions where students are divided into their PBL groups and work their way through a series of short and lengthy problems.

Year 2

The theme for year 2 is *Design as an Integrator* and the content of the year was such that the engineering science was introduced in the context of its purpose in the design aspects of engineering. Year 2 is the first year in which the engineering disciplines are divided into degree specific streams, Aerospace Engineering and Mechanical Engineering. For space limitations, details are provided here for the Mechanical stream only.

The format of year 2, in terms of structure, is significantly different than that in year 1. In year 2 the year is divided into four, 6-week periods. In each of these periods the course focuses on particular aspects of the degree programme as illustrated in figure 3. Of particular note is the final period labelled *Integrating Module*. The purpose of this module is to bring all the various engineering sciences together to solve a particular problem, in this case the design of a reciprocating compressor. Engineering programmes typically compartmentalise topics, with the result that students are often unaware of the links between the various engineering subjects. The purpose of this module is to re-affirm the engineering science they have learned in the other units, expand upon this and to demonstrate how knowledge of many topics is typically required to solve an engineering problem.

Various methods of learning and teaching are adopted during the 6-week periods, with the overall aim being to exploit the problem solving skills that the students have acquired during the first year whilst ensuring that the students gain the necessary knowledge and understanding expected in the 2nd year of an engineering programme. To this end the students undertake the following activities:

- **Problem-based learning**: working in groups the students attempt to solve several problems in each 6-week period. These problems vary in length from 1 to 3 weeks and follow the PBL model described earlier.
- **Structured learning sessions**: these sessions take on a variety of forms depending upon the subject that is being investigated and include for example, question and answer sessions, lectures and tutorials. The purpose of these sessions is to provide some of the knowledge and understanding that is necessary to complete the PBL activities and also to place the particular subject that Are under investigating into the context of industrial practice.
- **Lectures**: *Human Resources and Business Organisation* and *Accounting and Law* are taught using formal lectures throughout the year. There is also a Design thread that runs through the year. This is taught using formal lectures and problem solving classes.

Years 3 and 4

The structure and content of years 3 and 4 is very similar to that in a traditional engineering programme, thus ensuring that there is no reduction in the engineering science knowledge of the graduate students. The method of delivery that is adopted in year 3 and 4 units is left to the discretion of the academic member of staff responsible for each unit. However, the method of delivery will be such that it will exploit the skills that the students have learned in years 1 and 2 and will also be suitable for the particular topic involved. For many units it is expected that PBL will be adopted.

The lack of significant changes to years 3 and 4 reflects the fact that the students tend to be highly motivated and enjoy the final two-years of the traditional engineering programmes.

PREPARATION

The introduction of PBL into the engineering programmes has brought with it a culture change for staff as well as students. Before the introduction of PBL into the programmes there were a series of training activities that were run for staff. These activities introduced staff to the concept of PBL and instructed them on how to be facilitators. All staff were given several opportunities to practice being a facilitator during the testing stage of the PBL activities.

FEEDBACK FROM YEAR 1

Year 1 of the new engineering programmes ran for the first time in the academic year beginning September 2001. General observations that have been made regarding the first year of the programmes are provided below:

1. Desirable learning outcomes can be successfully achieved through PBL.
2. PBL motivates the majority of students to attend and engage, however there are still some problems with *passengers* and non-attendance which needs to be addressed.
3. During PBL weeks, the students typically work for between 20-25 hours per week, which is lower than expected.

4. Whilst certain taught courses have been well received there is a belief amongst students that they should be more closely integrated with the PBL activities.
5. Whilst initially there was some resistance from members of staff to PBL, those that have been acting as facilitators during the first year have found the experience rewarding, despite their work-load increasing slightly.
6. During the PBL activities there are three timetabled facilitated sessions per week. Evidence suggests that this could be reduced to two.
7. A PBL group size of 5-8 works well.
8. An outcome of PBL is that staff are working much more in teams than under the more traditional lecture based system. Members of academic staff also have the opportunity to act as advisors during the development of new PBL exercises as well as being aware of the material being developed by other colleagues.

Whilst it is not possible to be definitive until the second year of the course begins, it would appear that the number of students withdrawing from the course has reduced compared with previous years. The number of students who are required to re-sit units has also reduced from 40% in 2001 to 27% following the introduction of PBL. The reasons for these reductions are believed to be that the students are indeed enjoying the course more than in previous years and through PBL facilitation, members of staff have much closer contact with students during the year. This closer contact means that it is possible for members of staff to identify and respond to *at risk students*.

EVOLUTION OF THE PROGRAMME

Following a thorough review of the first year it is evident that there are certain aspects of the course that require modification. To address the issues listed in the previous section, the following changes are planned for the start of the September 2002 academic year.

- PBL activities will be more closely integrated with the taught courses. This is to be achieved by removing the 2-week PBL, 2-week taught course format. Instead 1-2 week PBL activities will run every week of the year. During these weeks, taught courses will be timetabled for Tuesday and Thursday afternoons and Wednesday mornings. This change is expected to address the concerns described under points 3 and 4 in the previous section.
- The current assessment methods, which rely heavily on group marks, have meant that students have been able to become passengers. Proposed assessment methods will be modified to place greater emphasis on individual work.

CONCLUSIONS

This paper has described the introduction of PBL into the undergraduate programmes offered by the School of Engineering at the University of Manchester. Whilst the introduction of PBL into an engineering programme is not novel, the scale to which it has been adopted at MSE has not been seen elsewhere in the UK. The expectation of the programmes is motivated, enthusiastic students who are familiar with the roles and responsibilities of professional engineers.

It has already become apparent that within small groups, it is much easier and quicker to identify and respond to *at risk students*, since absenteeism is immediately noted, and it is anticipated that this will have a positive effect on progression and retention rates within the School.

The reception from industry and the professional accreditation boards of the Institution of Mechanical Engineers and the Royal Aeronautical Society has been very positive and the move to the PBL method of delivery was described by the Professional boards as ‘fascinating and exciting’. The new programmes are expected to have a profound impact on the teaching of engineering science in the UK and around the world, and to place Manchester at the forefront of the development.

REFERENCES

[1] Vernon, D. T., & Blake, R. L., ‘Does problem-based learning work? A meta-analysis of evaluative research’, *Academic Medicine*, 68, 7, 1993, 550-563

[2] Woods, D.R., *Problem-based Learning: How to Gain the Most from PBL’*, Donald R. Woods, Waterdown, Canada

[3] Crowther, B. and Lennox, B., ‘Design and implementation of a hovercraft problem based learning exercise as part of a first year engineering programme’, International Conference on Engineering Education, UMIST, Manchester, UK, 2002

Problem Scenario
The ‘No Fear’ roller-coaster in the ‘Moss-Side Fantasy-Land and Cyber-City’ was recently opened by Brooklyn Beckham. It is the largest roller-coaster in Europe. During the first day of operation, an incident occurred where one of the cars was damaged. Fortunately, the car remained on the track and although the occupants in the fully laden car (all members of the University Sumo Wrestling team) were badly shaken, there were no serious injuries.

The front axle of the car concerned was found to be bent, but had not broken. No other damage was visible. Police have ruled out the possibility of vandalism. Manufacturing defects have also been eliminated as a possible cause.

The ride has been shut down pending an investigation into the accident. The owners are anxious to determine the cause of the accident so that their biggest attraction is up and running as soon as possible.

FIGURE. 1
PROBLEM SCENARIO

Week Number													
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Rocket PBL	IT/Comms	Renewable Energy PBL	Space Frame PBL	Electric Motor PBL	Taught Courses			Roller Coaster PBL		Taught Courses		Hovercraft PBL	

15	16	17	18	19	20	21	22	23	24	25	26	27-30
Taught Courses		IR Link PBL		Taught Courses		Powerful Bubbles PBL		Taught Courses		Power Plant PBL		Examinations

FIGURE. 2
STRUCTURE OF YEAR 1

Semester 1

Week	1	2	3	4	5	6	7	8	9	10	11	12
Topic	Statics and dynamics						Thermofluids					

Semester 2

Week	1	2	3	4	5	6	7	8	9	10	11	12
Topic	Control and instrumentation						Integrating module					

FIGURE. 3
STRUCTURE OF YEAR 2