# A School-wide Implementation

*This handout describes how the School of Engineering at Manchester has implemented a school-wide problem-based learning approach.*

*Although the approach described here is problem-based, it has much in common with project-based learning and many of the lessons will transfer readily into learning engineering through projects.*

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# Problem-Based Learning at the Manchester School of Engineering

This briefing explains how the University of Manchester's School of Engineering has successfully adopted Problem-Based Learning (PBL) to their hearts. It gives a taster of why they decided to turn their engineering course completely over to PBL and the implications in doing so. There's also an example of a problem to give you a better idea of how the process works.

## *Synopsis*

In September 2001, Problem based learning (PBL) was introduced as the primary teaching method for undergraduate engineering programmes at the University of Manchester.

The focus of problem-based learning (PBL) is to organise the curricular content around problem scenarios rather than subjects or disciplines[1]. Students work in groups or teams to solve or manage these situations but they are not expected to acquire a predetermined series of 'right answers'. Instead they are expected to engage with the complex situation presented to them and decide what information they need to learn and what skills they need to gain in order to manage the situation effectively. This radical approach was chosen in order to address:

- The changing skill base of University entrants, including lack of numeracy/ literacy
- The needs of industry for graduates with not only a solid foundation of engineering knowledge but also good communication skills, the ability to work in a team and solve problems.

The introduction of PBL brought many benefits and rewards for staff and students and also raised a number of challenges. An initial review of the programmes, conducted by an independent analyst, are encouraging. Observations from staff indicate that after completing the first year of PBL, the students are more confident of their own abilities, better able to work in a team, keener to learn and have a greater understanding of the practical aspects of engineering. It is anticipated that the programmes will produce motivated, enthusiastic students who are familiar with the roles and responsibilities of professional engineers. This method of teaching also resulted in decreased re-sits and end of year failures, progression from year 1 improved from 75% to 86% in the first year of PBL, which has a clear positive impact on retention rates.

The adoption of PBL has also had a significant impact on the conversion rate of applicants to firm acceptances within the UCAS system. The reception by industry, professional institutions, students and parents has been uniformly positive and described as 'unique' and 'innovative'. The RAeS and the IMechE awarded accreditation in March 2002 and were ‘excited and fascinated’ by PBL[2].

## ***Programme Development*** [3]

In 1998 a team of four people were assigned to develop the structure and content of the PBL based programmes with the intention that the programmes should take their first cohort of students in the academic year beginning September 2001. The early stages in this development involved identifying how PBL should be integrated into the undergraduate programme, what form PBL should take and the amount of PBL that should be contained within the programme.

There have been many PBL methods proposed for undergraduate education and the one adopted by MSE involved dividing the class into groups. Groups, typically of 8 students, are allocated pseudo-randomly at the start of the year, students are not allowed to change groups, and the groups are restructured at the start of the second semester.

Each group works on a problem for 1-2 weeks. A problem scenario is handed out to each group, the make up of which is selected at random at the beginning of each semester, on a Monday morning. Over the next 1-2 weeks, 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. To ensure that this happens, each group is assigned a member of staff who facilitates for two 1-hour periods each week. The role of the academic 'facilitator' is to guide the group to determine and achieve their own identified learning outcomes.

Continual self-evaluation is encouraged throughout the programmes, 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 tests, presentations, web page design, report writing and demonstrations (see later for credit ratings).

Before each PBL activity was introduced into the programme it was piloted extensively with the help of school students and third and fourth year students. This testing phase proved invaluable as the test students would often focus on unexpected aspects of the problem, rather than the desired engineering topics. Significant changes were made to the problem scenarios at this stage to ensure that the correct learning outcomes could be achieved.

A major problem facing the programme development team was that there was some resistance from many academic staff to the transfer to a PBL based programme. To encourage staff to support the transition to PBL, a series of away-days and training courses were scheduled between 1998 and 2001. These courses proved very valuable and changed the opinions of some academic staff, although others remained resistant, citing increased workload as their primary concern. Strong leadership was absolutely essential for PBLE to work, the half way solution would not have been as effective.[4]

## *Programme Structure*

It was decided at an early stage in the planning that PBL would be used extensively in years 1 and 2. In years 3 and 4 staff are permitted to utilise the most appropriate teaching method for the aims and objectives of the units. Staff are encouraged to build upon the skills developed within the students during the first two years of the programme.

Year 1, which both Mechanical and Aerospace engineers take jointly, is split between PBL activities and structured learning (which takes a different form to conventional taught modules) to ensure an appropriate coverage of the first year syllabus. The PBL activities cover the majority of the core engineering science with the structured learning providing theoretical underpinning and filling in any gaps in the syllabus not covered in the PBL activities.

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. To ensure that PBL would be suitable for an engineering programme, and to reinforce material, structured learning sessions were integrated within the programme. Care was taken to ensure that the structured learning sessions did not take the form of traditional lectures, as this did not exploit the skills that the students were learning through PBL and was seen as the primary cause for students becoming disengaged with engineering in the past. Consequently the taught courses took the form of 2-4 hour sessions, during which the students would receive several short 15 minute presentations, interspersed with several individual example sheets and group based problem solving activities.

Within the first 5 weeks of the year 1 programme the students complete a series of 1-week PBL activities. The purpose of these sessions is for the students to get to know the other members of their group and to learn about PBL and to discover how to get the most out of it. The basic structure of the rest of year 1 is that it is divided into 12 two-week blocks. In each two-week block the students undertake PBL activities in the morning and engage in more structured teaching in the afternoons.

The theme for year 2 is *Design as an Integrator*. In year 2 engineering science is introduced in the context of its purpose in the design aspects of engineering. This is the first year in which the engineering disciplines are divided into degree specific streams, Aerospace Engineering and Mechanical Engineering.

The second year is divided into four, 6-week periods. In each of these periods the course focuses on particular aspects of the degree programme, for Mechanical Engineering students these are ‘Statics and Dynamics’, ‘Thermofluids’, ‘Instrumentation and Control’ and an ‘Integrating Module’. The purpose of the integrating module is to bring all the various engineering sciences together to solve a particular problem, in this case the re-design of a reciprocating compressor. This approach equates to the 'integrating projects' which are sometimes adopted in traditional programmes.

As with year 1 the teaching methods employed in year 2 comprise a mixture of PBL and structured learning sessions. In year 2 the two teaching methods are more closely aligned.

## *Example problem* [5]

One problem that the students face in first term of the first year is the Space Frame Problem:

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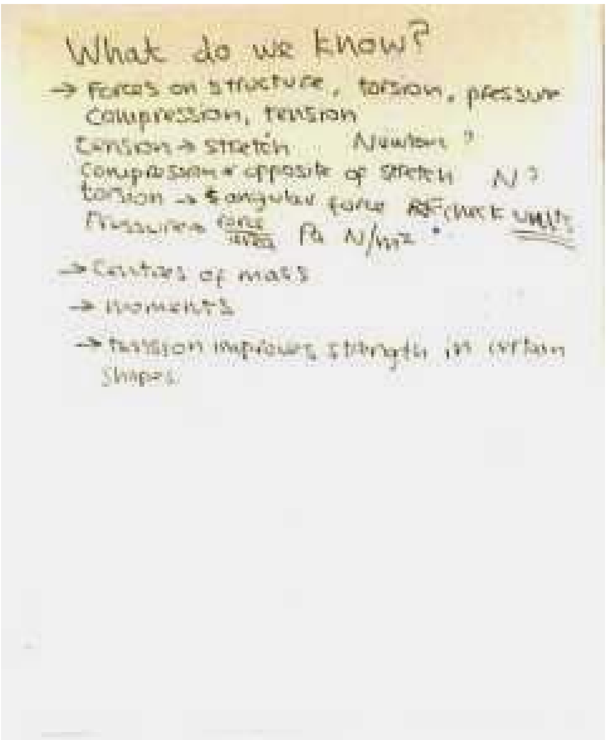
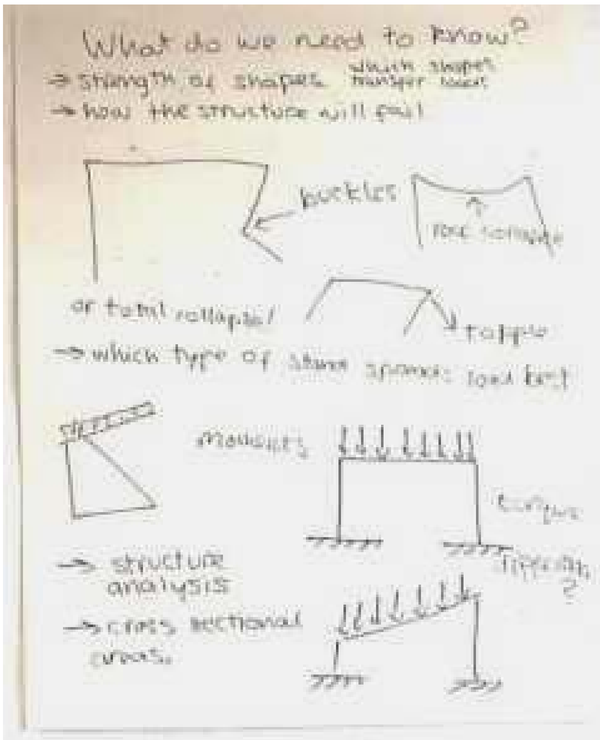
### Problem description

To cater for their increased level of football support, Tranmere Rovers need to construct a new stand. The new stand is required to have a roof so that the supporters underneath don't get their expensive clothing wet. The location of the new stand will be in an area that is notorious for high levels of snowfall. The stadium designers wish to test a model of the stand profile to ensure that it is strong enough.

It is proposed that the leading dimensions (floor area) of the stand will be 100m long by 63m deep. The upright members supporting the roof must not cover more than 0.5% of the floor area, to allow maximum room for the fans. The uprights must be inside the given area - there is no room outside. The height of the stand should be at least 30m high at the front, and 10m high at the rear. This allows for clear sight of the football pitch, as well as banners and other aerial activities with which football supporters show their enthusiasm.




**The groups begin to answer the problem by asking themselves: "What do we know?" and "What do we need to know?"**

### Resources

Paper: standard 80gsm photocopier paper, Cotton thread, Glue.

## Practical test specification

The model is to be built to approximately 1/300 scale, i.e. about 333mm x 210mm. The height is not fixed, but has a minimum height. The upright members supporting the roof must not cover more than 0.5% of the floor area.

The "snow loading" will be simulated by adding layers of A4 paper (297mm x 210mm) or sand until the structure fails. The model should support a minimum of 1kg (200 sheets). It will sit on a flat base for testing. The "roof" must be capable of supporting either a paper load (it must not slide off) or sand (which must be evenly spread, not just piled in the middle).

The model must be built from paper, cotton thread, and glue only. Examine the marking strategy carefully - there is a "cost" penalty for heavy designs.

**Students making their model frame**

## Assessment

The assessment for this problem has four parts, some undertaken by the individual [I] and some by the group [G]:

- Short test of concepts related to activity (20%) (two attempts allowed) [I]
- Poster explaining how the space frame works and results of modelling (10%) [G]
- Practical demonstration of space frame strength measured against specification (20%) [G]
- PADP: Personal journal review (50%) [I]

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## *Peer Review*

The most significant issue encountered with the PBL programme is that associated with ‘passengers’. A group may contain 1 or 2 students that provide little or no contribution. To address the problem a peer review scheme was introduced. At the end of each PBL activity the students provide a grade, out of 5, for the contribution that each member of the group has made. These figures are then processed and individuals are given a mark, using an electronic peer moderation system, that preserves the group mark. Students can appeal if they believe they have been unfairly treated by their peers but must provide factual evidence to confirm that they have contributed. This evidence typically takes the form of minutes and attendance from the meetings that are routinely held during the PBL activities.

## *Reflection*

Following the completion of the first year of the programme an independent analysis was conducted. The main conclusions from this analysis (through feedback forms and interviews with staff and students) were that:

- Desirable learning outcomes can be successfully achieved through PBL.
- A group size of 5-8 works well.
- Staff training is required to learn to facilitate
- Staff have found facilitation a relatively rewarding experience and that it doesn't provide a significantly increased workload
- Adopting a PBL approach has taken a lot of effort on behalf of a small number of staff who have piloted the programme through internal and external review.
- PBL motivates the majority of students to attend and engage, although it does not eradicate problems with *passengers* and non-attendance.
- The structured learning sessions have been particularly successful with many students (surprisingly) rating Mathematics as their favourite unit.
- Short repeated PBL comprehension tests are popular with the students and help to ensure PBL technical learning outcomes are covered.
- The number of students who were required to re-sit units reduced from 40% in 2001 to 27% following the introduction of PBL and the progression from year 1 improved from 75% to 86%. This can be attributed to; increased enjoyment of the course by the students and the ability of staff to identify and respond to *at risk students,* due to much closer contact with students through PBL facilitation.

## *References*

1 LTSN Generic Centre, UK Problem-based learning web site, supported by the LTSN Generic Centre and hosted by Coventry University; http://www.hss.coventry.ac.uk/pbl/

2 Cooper J., Management of change - converting an entire school to problem-based learning - Lessons to be learned, LTSN Engineering Projects Workshop Sept 2003; http://www.ltsneng.ac.uk/downloads/events_dl/Project_groupwork/cooper.ppt

3 Lennox B., Teaching Engineering through Problem Based Learning, Case Study, PBLE Guide, p2-55 to p2-60, 2003; http://www.pble.ac.uk/guide-final-2003-08-12-v11.pdf

4 Wood N., Problem Based Learning and Its Application to Engineering, EPC Annual Congress, April 2003; http://www.engprofc.ac.uk/pres/cong2003/cong_2003_wood.pps

5 Williamson S., Hopping B., Case Study - Problem-Based Learning at the Manchester School of Engineering; http://www.ltsneng.ac.uk/er/features/pbl.asp