Design and implementation of a hovercraft problem based learning exercise as part of a first year engineering programme

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Abstract *¾ The Manchester School of Engineering now uses Problem Based Learning (PBL) to deliver core engineering science learning in the first year of its undergraduate programme. This paper describes the design and implementation philosophy for PBL units, using a PBL based on the design and make of a hovercraft as an example. PBL documentation is presented in terms of a student pack and a facilitator pack. The hovercraft PBL was run for the first time in January 2002. Overall, the PBL was successful in delivering the majority of the intended learning outcomes. However the group based programming exercise and expert forums were less successful. Furthermore, there is opportunity to beneficially increase the level of challenge posed by the Hovercraft and other first year PBL units.*

Index Terms ¾ PBL, design, implementation, engineering, fluids

INTRODUCTION

From September 2001, the Manchester School of Engineering (MSE) adopted Problem Based Learning (PBL) as the primary teaching method in its undergraduate programmes. Whilst PBL itself is not innovative, its application to engineering and in particular to the first year of an engineering degree course is. MSE is the first School of Engineering in the UK to adopt this radical approach, which has involved a transformational cultural change for both staff and students. Details of this change may be found in 'Changing structures for delivery - breaking traditional barriers', Lennox et al, in the current proceedings.

The present paper seeks to document the design and implementation of a fluids based PBL unit for the new engineering first year structured around the design of a hovercraft vehicle.

GENERIC PBL DESIGN PROCESS

An important outcome from the PBL design experience at Manchester is that PBLs and traditionally taught units must be integrated at the programme design stage. Isolated units delivered by PBL can be made to work, however, implementation can be problematic with students finding conflicting demands between PBL and more traditional learning styles. Furthermore, it has been found that the most successful engineering PBLs deliver learning outcomes across a range of traditional taught course boundaries.

The basic process used to design PBLs for the new engineering programme is as follows:

- Identify core learning outcomes to be achieved
- Identify a series of scenarios that provide a learning context for the desired outcomes
- Develop PBL activities based on identified scenarios

Each PBL is accompanied by the following documentation:

Student Pack

- Problem statement
- Learning themes addressed by the PBL
- PBL timetable
- Description of assessments

Facilitator Pack

Student pack plus:

- Desired learning outcomes
- Progress monitoring chart
- Facilitator technical notes

HOVERCRAFT PBL EXAMPLE

Problem Statement

"*A company that makes electrically powered ducted fans is considering developing a small, remotely controlled hovercraft for transporting payloads over a reasonably flat surface. The board of directors have requested detailed technical information on how the hovercraft will work and its likely performance backed up with experimental data. Following this, a demonstration of a prototype vehicle is required.*

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A hovercraft simulation programme is currently being developed in-house to investigate manoeuvre dynamics, however the code is not yet complete. A ducted fan rig and pressure measuring equipment is available in the lab."

Learning Themes

The engineering first year at Manchester has 9 learning themes running though it, with material delivered through PBL and more traditional taught units. The hovercraft is a cross-disciplinary PBL and contributes to all 9 of the first year learning themes, Table 1.

	First Year Learning Theme ⇩	Material covered by Hovercraft PBL
1	Personal Development	✍
2	PBL Personal Study	✍
3	PBL Group Work	✍
4	Design	✍
5	Maths	✍
6	Mechatronics	✍
7	Professional Engineer	✍
8	Statics and Dynamics	✍
9	Thermofluids	✍

TABLE 1 LEARNING THEMES ADDRESSED BY THE HOVERCRAFT PBL

Project Plan

The format for a standard two-week PBL is shown in Table 2. The contents of this plan as explained as follows:

Facilitated sessions
F1-5 Group meetings facilitated by a member of staff (see Appendix A for Facilitator progress monitoring chart)

Expert Forums
EF1 Ducted fans and hovercraft fluid dynamics
EF2 Visual basic and dynamic simulation

Assessment
A1(I) Test of concepts related to activity
A2(G) Poster explaining how a hovercraft works and experimental determination of fan thrust from pressure measurements
A3(G) Hovercraft Visual Basic Simulation
A4(G) Practical demonstration of hovercraft functionality measured against specification

(G) = group assessment, (I) = individual assessment

Description of Assessments

PADP Personal Development

Completion of Personal Academic Development Plan (PADP) for the Hovercraft activity.

PBL Personal Studies
A1. Test on analytical concepts relating to the PBL.
A tutorial sheet will be distributed after the second facilitated session on the first Wednesday. On the following Wednesday there will be an open book test under exam conditions based on questions similar to those in the tutorial sheet.

PBL Group Work
A2. Poster (40%)
Aim: to provide an explanation of a how the proposed hovercraft works and to explain how fan thrust can be obtained from pressure measurements. The poster should include an explanation of relevant theoretical fluid

Event	Mon		Tues		Wed		Thur		Fri				Mon		Tues		Wed		Thur		Fri	
Facilitated sessions	F1				F2				F3						F4				F5			
Expert Forum								EF1								EF2						
Assessment										A2							A1			A3	A4	
	PADP																					

TABLE 2 PROJECT PLAN FOR THE HOVERCRAFT PBL

concepts and experimental results where available. The target audience of your poster is a professional engineer who does not have a fluids background.

3. Visual Basic Simulation (20%)
An executable (.exe) version of the final Hovercraft simulation developed by the group.

4. Hovercraft Fly-off (40%)
Hovercraft are required to negotiate an obstacle course layout in the Engineering Foyer. Track walls will be 5cm high approx, max step height of obstacles 2cm approx. Hovercraft will be assessed on functionality (70%) (based on lap time), innovation (20%) and style (10%).

Learning Outcomes

Knowledge and understanding

1. static, dynamic and total pressure
2. experimental techniques for measuring pressure
3. continuity and the Bernoulli equation
4. free body diagrams
5. Newtons laws of motion

Thinking skills

6. calculate force on a body due a static pressure distribution
7. apply continuity and Bernoulli's equation and actuator disc theory to the analysis of ducted fans
8. calculate of centres of gravity and inertia
9. use free body diagrams and Newtons laws to assess vehicle statics and dynamics

Practical skills

10. electrical circuit construction
11. experimental techniques for measuring pressure, velocity and flow rate
12. vehicle design and construction
13. use of radio control

General transferable skills

14. problem solving
15. team working
16. poster presentation

IMPLEMENTATION

The Hovercraft PBL ran for the first time in January 2002.

- Year cohort was divided in to 17 groups of 8 students
- 4 sets of experimental equipment provided
- Each group provided with raw materials (foam board) for model manufacture
- Each hovercraft equipment kit (electronics/fan/battery) cost approximately £100
- Each kit shared between two groups

REFLECTION AFTER FIRST YEAR OF IMPLEMENTATION

Hovercraft PBL

- Students on the whole rated the Hovercraft PBL as enjoyable exercise in which they learnt a range of engineering science and gained useful new skills
- The original problem did not provide a sufficient range and depth of challenge for all students. This has now been addressed by providing a more clearly implied objective for the experimental work and by increasing the performance needed to complete the obstacle course.
- The programming aspect of the PBL was relatively unsuccessful in that 25% of groups failed to submit a completed programme and for those groups who did, most work seemed to have been done by single individual. This problem is being addressed by adding an individual component to the programming assessment and introduction of a programming PBL earlier in the year.
- The expert sessions for the PBL were not particularly successful, with relatively low attendance and little added value for those who did attend. There was also a temptation to use the expert session as a back door way of giving out the 'answers' to the problem.

Design of engineering PBLs in general

- PBL can be used to deliver meaningful learning outcomes as part of a first year engineering course
- Successful implementation of PBL requires careful integration of PBL and more traditional taught courses
- Practical PBLs are harder to design (real world constraints) and implement (resource issues) than paper based PBLs. However, the majority of students prefer PBL with some practical application
- Cross disciplinary PBLs tend to provide a richer learning environment for students compared with PBLs that focus on just one area of engineering science
- Fair and just assessment of the individual in PBL is essential to the successful functioning of student teams

APPENDIX A FACILITATORS' PROGRESS MONITORING CHART

Day	Activities	Expected progress
Monday	• Facilitated Meeting 1 • Internet search • Library search	*How does a hovercraft work?* • What exactly is a hovercraft? • What is a ducted fan and how does it work? • How does a hovercraft hover? • How high does it hover off the ground? • How does a hovercraft propel itself forwards? • What is meant by the word 'performance' in an engineering context?
Tuesday	•	• Find or derive equations for flow, thrust and power for a ducted fan. • Use motor electrical power rating and fan area to estimate flow rate, thrust and power • Calculate duration from battery capacity. Range can be estimated by product of estimated speed and duration. As a rough estimate, maximum speed can be estimated from equating drag with thrust. Take CD to be equal to 1 and estimate a frontal area.
Wednesday	• Facilitated Meeting 2 • Tutorial sheet	*Preparation for experimental work* • How do you measure static and total pressure? • What is the expected total and static pressure distribution through the fan? • How can ducted fan volume flow rate, thrust and fluid power be obtained from pressure measurements? • How do you measure the electrical power absorbed by the motor? • How do you characterise the performance of a ducted fan?
Thursday	• Expert forum • Experimental work • Poster preparation	EF 1: An expert will be on hand to answer questions concerning ducted fans and hovercraft fluid dynamics Theoretical prediction of skirt clearance
Friday	• Facilitated Session 3	*Poster preparation* Students should have predicted and/or measured • Fan volume flow rate, thrust and power efficiency as a function of motor current • Max payload as a function of skirt clearance • Typical mission duration on one battery charge
Monday		Visual basic programme should be analysed and areas needing completion identified
Tuesday	• Facilitated Session 4 • EF2	*Hovercraft dynamics* • What is the best location/orientation of the thrust fan for manoeuvering the hovercraft? • Visual basic programme should be running (post EF2)
Wednesday	• Test	A prototype should be reading for testing Thursday afternoon
Thursday	• Facilitated Session 5 • Hovercraft Build and test	*Hovercraft build and test* • Where should the centre of gravity be? • What is the optimal planform area for the hovercraft? • What are the best locations for the lift and thrust fans? • Will stabilising fins be an advantage?
Friday	• Fly-off	Hovercraft demonstration Write-up PADPs