

EDUCATING ENGINEERS AS IF THEY WERE HUMAN: PBL IN CIVIL ENGINEERING AT THE UNIVERSITY OF LIMERICK.

Tom Cosgrove, Declan Phillips* and Michael Quilligan

University of Limerick

Abstract: The authors' experiences designing and implementing a new problem based learning (PBL) programme in Civil Engineering at the University of Limerick is described. Focus groups, student and staff learning logs, teaching evaluations, a variety of assessment formats, tutorial dialogue, in-class quiz techniques and informal conversations are used to build a picture of the staff and student experience so far. The authors reflect on their educational priorities, their extensive experience in university education and in professional training and mentoring.

Approaches to specific PBL challenges including timetabling, problem design, PBL process facilitation, integration of learning across subject boundaries and assessment are described.

Keywords: problem based learning, PBL, civil engineering education, innovative teaching, assessment, pedagogy.

**Correspondence to: Declan Phillips, Faculty of Science & Engineering, University of Limerick, Ireland. E-mail: declan.phillips@ul.ie*

1. INTRODUCTION

The Civil Engineering programme at the University of Limerick (CIVIL @ UL) is unique in Ireland in that it is delivered with Problem Based Learning (PBL) at its core. As the programme nears the end of its second year this paper presents the background, highlights from the story so far and reflections of the staff involved in designing and implementing this new programme.

2. PROGRAMME INTENT

The goal of CIVIL @ UL is, through engineering education, to develop people with a life-long research orientation who can address complex problems in the built and managed environment, developing solutions rationally but creatively by collaborating within teams.

This goal requires the development of appropriate attitudes and habits of mind such that the learner takes responsibility for their own education and develops a lifelong mental habit of reflection (Cowan, 1998). Sir Charles Inglis, former Head of Engineering at Cambridge University encapsulates this succinctly when he states '*the soul and spirit of education is that habit of mind which remains when a student has completely forgotten everything he has ever been taught*' (Inglis, 1941 cited in May, 2009).

Therefore CIVIL @ UL is concerned with:

- personal responsibility for learning
- a research orientation
- reflective practice
- group working and
- communication and presentation skills

We have chosen PBL as the most effective means to achieve these ends. These concerns are process led rather than content driven. Attitudes and habits are not formed by transmitting content, but by embedding work with appropriate content within an effective process. This process is designed to effect behaviour change. That is our mission at CIVIL @ UL.

3. TEACHING AND LEARNING RESEARCH

3.1 Effective teaching practice

As we move our students towards a research orientation we must ourselves inform our practice by research. In designing an effective process we are mindful, from educational research, of a number of conclusions on effective teaching strategies. See, for example, Felder and Brent (2003). The most important for our purposes are summarised as follows:

- Activity (as distinct from passive listening)
- A variety of modes of engagement (visual/verbal, active/reflective etc)
- A task or challenge (i.e. a reason or motivation to seek knowledge)
- A connection with personal experience (a concrete application)
- Use of historical precedent as a context (see Phillips, 2010)
- An opportunity for individual self expression
- Social contact (group activities)
- A teacher who inspires respect.

What promotes respect for the teacher?

- Authority or mastery of the subject matter
- Enthusiasm: demonstrate your conviction that the subject matter is important
- Care: demonstrate concern for and empathy with the students.

3.2 A culture of care

One manifestation of care is to listen to the students' experience of the programme. Research has in this area has unequivocally established that 'student evaluations have high levels of reliability and validity' (Felder and Brent, 2008). As we developed CIVIL @ UL, anonymous feedback has been gathered by the UL Centre for Teaching and Learning using focus groups and on line student evaluation of lecturers and facilitators.

4. WHAT IS PROBLEM BASED LEARNING?

4.1 Common features

Definitions vary but some common features occur. PBL organises curricular content around a problem that stimulates the student to research and learning, generally in a group setting. Lectures deliver content relevant to the problem at the appropriate stage in the PBL process. The alternative term 'trigger' instead of 'problem' points to a distinguishing feature of PBL:

the aim is not necessarily completion of a project but the use of a problem as a ‘trigger for learning’. The term ‘problem’ is adopted here.

4.2 PBL in medicine and engineering

The development of PBL is most advanced in the field of medical education, in particular at McMaster University in Canada (Barrows and Tamblyn, 1980) and Australia, but also in the UK and Europe. Most recently the Graduate Medical School (GMS) at UL has been championing PBL for the past four years.

Among the drivers for the adoption of PBL in medicine was the poor knowledge retention rate reported from conventional programmes, the explosive growth in medical knowledge requiring a lifelong research orientation for medical professionals and the increasingly collaborative nature of medical practice (Barrows and Tamblyn, 1980).

It is interesting to compare current concerns cited in May (2009) on the attributes of many of today’s engineering graduates:

‘They lack basic skills: thinking it out for themselves, designing, writing, drawing, sketching, presenting, calculating, validating. They have assimilated a lot of knowledge but do not know how to use it effectively.’

This quotation resonates powerfully with the authors’ own experience gained mentoring some dozens of graduate engineers in practice over 40 years.

The PBL approach is now established in a number of civil engineering programmes worldwide, notably at Aalborg in Denmark (Hansen and Soerensen, 2003), New South Wales, University of Castilla – La Mancha, Spain and Monash University, Australia.

4.3 PBL and CIVIL @ UL

The proximity of the GMS has afforded the staff of CIVIL @ UL the opportunity to observe a well established PBL process in operation first hand. We have used the GMS process as a model for our own practice and have adopted the following process steps in our approach:

At the first PBL session:

- Appoint scribe
- Brief/problem presentation
- Clarify unknown terms and request essential missing information
- Brainstorm existing group knowledge and solutions
- Organise knowledge
- Propose a tentative solution
- Identify knowledge gaps
- Make research plan
- Scribe reads research plan for transcription by group
- Adjourn.

Between sessions

- Conduct self-study and research, meeting informally as necessary.

Second and subsequent sessions:

- Reconvene
- Read research plan
- Table research
- Organise new knowledge
- Revise or develop solution in light of new knowledge to eventual completion

Our PBL sessions consist of 2 tutors or facilitators and between three and six student groups, with about six students per group (Figure 1). The process promotes knowledge transfer across subject boundaries as all exiting group knowledge is pooled during brainstorming.



Figure 1 PBL Group activity



Figure 2 Trial pitting for geotechnical PBL

4.4 PBL in CIVIL @ UL Semester 4

We now describe the implementation within the Spring semester of Year 2. The structure of the Semester 4 programme is shown in Figure 3.

Thus there are three PBL problems running in Structural Steel and Timber Design (Siege Platform at King John's Castle), Hydrology and Water Engineering (A self-sufficient water supply for UL) and Geology and Soil Mechanics (Geotechnical flood protection structures at UL).

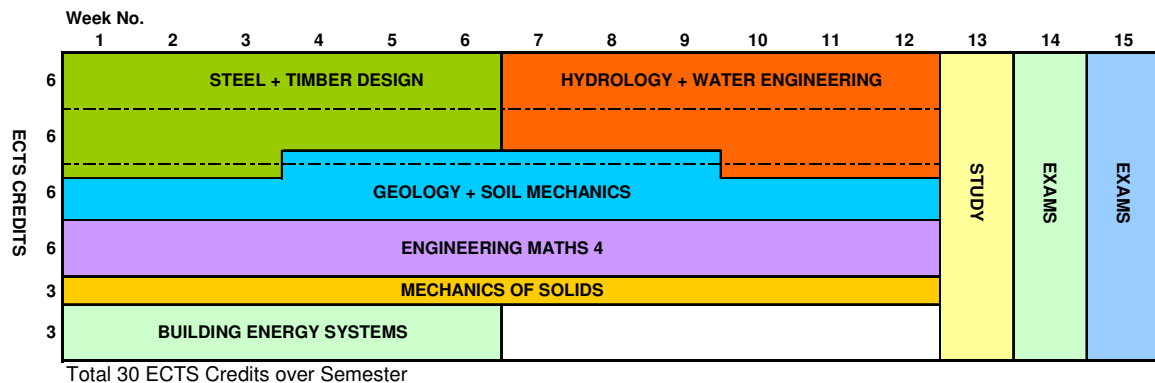


Figure 3 Semester 4 Timetable

5. THE SIEGE PROBLEM

This section describes one of the PBL examples.

5.1 Siege problem design

For Steel and Timber Design the problem was the design *and construction* of 6m high siege platforms at King John's Castle in Limerick. See www.ul.ie/civileng for a video account of the actual siege and Cosgrove (2010) for further background.

Good problem design requires time. Two facilitators critiqued the problem design by solving it including detailed consideration of the construction phase. This reduced problems on implementation. The brief was supplemented as necessary during the PBL sessions.

5.2 Allow for individual creativity

Feedback from students is emphatic that engagement is significantly enhanced when students can express their own creativity during the PBL process. We have therefore moved away from multiple short closed problems to open problems (such as the siege platform) that allow for personal creativity in the solution.

5.3 A single problem per module

A short problem may sometimes be used in first year to give both students and staff the opportunity to practise the PBL process. A single well designed problem, such as the siege problem, can achieve all the required learning outcomes. A supplementary tower problem (design only) extended the timber learning into the steel domain and exposed the students to the nuanced differences in approach required for the two materials. A rich diversity of solutions emerged. Figures 4-6 illustrate some stages in the solution process.

After construction and prior to assessment a session is devoted to reflecting on memorable learning that occurred.

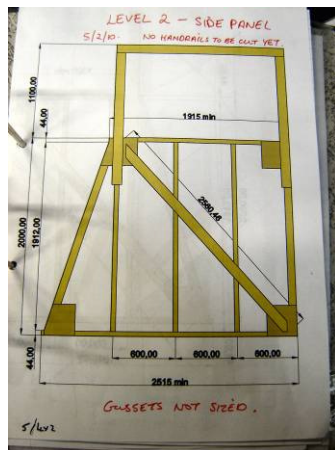


Figure 4 Design



Figure 5 Assembly



Figure 6 On Site

6. ASSESSMENT

6.1 Assessment by faculty

Students use a variety of media for submitted work. The students share two modules of Drawing and Representation in first year with the School of Architecture students. The importance of hand sketching is emphasised as both a representation and enquiry tool. A variety of pencil and paper techniques, some free hand, some with t-square and drawing board including perspective, isometric, axonometric and plan-section-elevation are taught.

The students presented their siege platform solutions using A0 posters at individual 15 minute interviews. The poster describes the concepts, the decision process (including discarded solutions) and the final solution. A guidance document discourages transcription of

text and encourages thoughtful use of sketching with carefully considered annotation. Moreover, the recent Geology and Soil Mechanics project required video and slide formats with or without audio. For some short problems outputs may be in report format and submitted online via the university learning management system SULIS.

The promotion of reflective practice is informed by research literature (e.g. Cowen, 1998). To this end a learning log is used throughout the PBL process recording brainstorming, solutions and, critically, reflections or 'thoughts about thoughts'. These are reviewed at mid-semester and general feedback is provided to the groups; final marking is at semester end.

Finally, to ensure that fundamental concepts are not missed during the group work we use an end of semester exam carrying between 30% and 40% of the module marks to assess mastery of essential fundamental concepts. The students are notified in advance of the concepts to be examined.

6.2 Self and peer assessment

Presentations and reflective learning logs are accompanied by student self and group assessment submitted online semester end using four criteria developed by the students during an early PBL session:

- Attendance
- Courtesy
- Completion of agreed work between sessions
- Engaging and contributing during sessions

To prioritise the importance of the 'work' component we assigned negative marks only for poor attendance and courtesy. This emphasises that these behaviours are a minimum expectation.

We have found engagement with self-motivated research between sessions uneven. However, we are promoting the desired behaviours by a weekly self assessment using a list of behavioural questions developed in Finland (Haaga-Helia, 2010).

7. TIMETABLING

7.1 Session requirements

PBL work requires minimum two or three hour sessions. There are typically two PBL sessions per week, ideally on a Monday and Thursday with lectures interspersed.

Based on previous feedback from student focus groups we structured Semester 4 with two PBL modules following in series rather than in parallel. Thus the siege problem was allocated the time of a 12 credit module for six weeks. Student feedback has confirmed a positive impact on time management. Geology and Soil Mechanics still ran in parallel but laboratory and other workload items were timetabled to avoid busy periods within the siege problem.

Where PBL is combined with significant non-PBL programme elements strong support from Departmental Heads and good collegial working relationships are required for success.

7.2 Lectures within PBL sessions

Supporting lectures designed for the specific problem may be given by lecturers not involved in the PBL sessions. Experience suggests that where the lectures are physically remote from the PBL working area attendance suffers.

Lecturers use interactive 'clickers' for multiple choice pop quizzes in accordance with good active learning practice. Students are required to purchase these clickers. Some of these quizzes are graded. The interactive display of the response frequency together with the right answer gives powerful feedback in real time to students and to the lecturer. Depending on responses, lecturers may repeat or modify material that is presenting difficulties. We find this technology an efficient and powerful teaching aid.

8. TRANSITION FROM SECOND LEVEL

8.1 PBL in first year

Moving from second level to third level is a challenging transition and facilitator awareness of the challenges faced by the students is important (Savin-Baden, 2000). Critical new habits are established during this transition. We introduce students to the PBL process in first year using the best achievable arrangement of modules and timetabling. This moves the student decisively forward into the new habits required in thinking and behaviour.

9. ONGOING ISSUES

PBL shares some characteristics with the kind of work involved in a final year project (FYP). Many university staff will have experienced the tendency of students to commit excessive time to a FYP at the expense of other modules. PBL shares this tendency. Where PBL is partially implemented this issue needs ongoing management. Facilitators may need to intervene regularly to shorten the research cycle.

Maintaining the balance between developing new habits of self-directed research and time management is an ongoing challenge for both staff and students. In this context it should, however, be noted that some students' expectation of the time commitment required in an engineering degree programme may be unrealistically low. A 5-module programme in ECTS terms has an expectation of a 50 - 60 hour per week commitment. End of term cramming was never a good educational practice. With PBL it is an impossibility.

10. FINAL THOUGHTS

The overall experience of all three authors has been energising and immensely rewarding. Students' feedback is likewise for the most part extremely positive with regard to the PBL experience. Course Director Dr. Declan Phillips, who has the longest teaching experience of the three authors, reports:

"In fifteen years teaching at third level, I have never encountered questions as considered and as probing as those received on the geotechnical flood defence project. For the first time I felt that I had engaged the students in soil mechanics by presenting a problem that students could see themselves encountering in their professional lives. Some

groups exceeded my expectations with the depth and rigour of their work. Moreover, I would go as far as to say that the entire class now knows and understands more about soil mechanics and its important role in construction than they would, had I delivered the module didactically as I have for the past four years.”

11. REFERENCES

Barrows, H.S. and Tamblyn, R.m. (1980) Problem-based learning, An approach to Medical Education, New York: Springer

Cosgrove, T. 2010. Process before Content: Learning from Defeat in Siege Warfare. Conversations around innovative PBL University of Limerick. Url: <http://www.ndlr.ie>.

Cowan, J. 1998. On Becoming an Innovative University Teacher: Reflection in Action SRHE and OUP.

Felder, R.M. and Brent, R., 2003. Learning by Doing. *Chemical Engineering Education*, 37(4), 282-283.

Felder, R.M. and Brent, R., 2008. Student Ratings of Teaching : Myths, Facts and Good Practices. *Chemical Engineering Education*, 42(1), 33-34.

Haaga-Helia, 2010. Problem Based Learning Assessment and Evaluation Tools. *Haaga-Helia University of Applied Sciences*. Url: <http://myy.helia.fi/~liibba/assessment>.

Hansen, L.P. and Soerensen, C.S. 2003. The Educational System in Civil Engineering at Aalborg University, Denmark. International Meeting in Civil Engineering Education, 18-20 September 2003, Ciudad Real, Spain p. 12, Ciudad Real, 2003.

Inglis, C.E. 1941 Presidential Address of Professor Charles Edward Inglis, *Journal of the Institution of Civil Engineers*, 17(1), 1-18.

May, I. 2009. What Should we Teach in Structural Engineering Design? *Proceedings of ICE, Civil Engineering*, 162, Nov 2009, 187-191.

Phillips, D. T. 2010. Education: The Challenge and How Forensic Engineering can Help, *Forensic Engineering 2009: Pathology of the Built Environment, Proc of the 5th Congress on Forensic Engineering*, ASCE, Washington D.C., 517-526.

Savin-Baden, M., 2000. *Problem-based learning in Higher Education: Untold Stories*. Buckingham: Open University Press/ Society for Research into Higher Education.