5. DESIGNING A HYBRID PROBLEM-BASED LEARNING (PBL) COURSE: A CASE STUDY OF FIRST YEAR COMPUTER SCIENCE IN NUI, MAYNOOTH.

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INTRODUCTION

The majority of students entering university in Ireland come directly from second level education, where the pressure is on students to achieve points to secure a place in university. This pressure leads students to approach learning as a task in which they memorise, store and reproduce information. This type of learning, commonly called 'surface learning', is not a suitable learning strategy in computer science, as the ability to solve problems is a vital element within the computer science discipline. In addition to solving problems, another essential skill that must be mastered by computer science students is computer programming. This involves students learning 'a programming language', which can be viewed as a set of formal specifications involving syntax, semantics and vocabulary. This in effect means that first year computer science students are required to understand a problem, develop an algorithm to solve the problem and implement a solution to the algorithm using a programming language that will result in the production of a concrete computer programme.

It is well accepted within the computer science community that first year students find programming difficult. One of the major stumbling blocks is the abstraction of the problem to be solved from the exercise description (McCracken et al, 2001). In order to overcome these inherent difficulties, we set about implementing an alternate pedagogical approach to a first year programming module. Our overall objectives were to improve the students' ability in problem abstraction, problem definition and problem refinement, to alter the pattern of learning that resulted in 'surface learning' to one that enhanced 'deep learning', and to make students responsible for their own learning.

PASSIVE TO ACTIVE LEARNING

Students taking the first year programming module come from three distinct disciplines: software engineering, arts and science. Previously the module was taught with a traditional approach combining three fifty-minute lectures and one three-hour lab per week. Tutorials with voluntary attendance were also available during the lab times. Due to constraints within the university timetable, we were unable to change the time slots allocated to us; however, we did change how we used the time.

Duch et al (2001) state that Problem-based Learning (PBL) instruction addresses the ability to:

- Think critically and be able to analyse and solve complex, real-world problems
- Work cooperatively in teams and small groups
- Demonstrate versatile and effective communication skills, both verbal and written

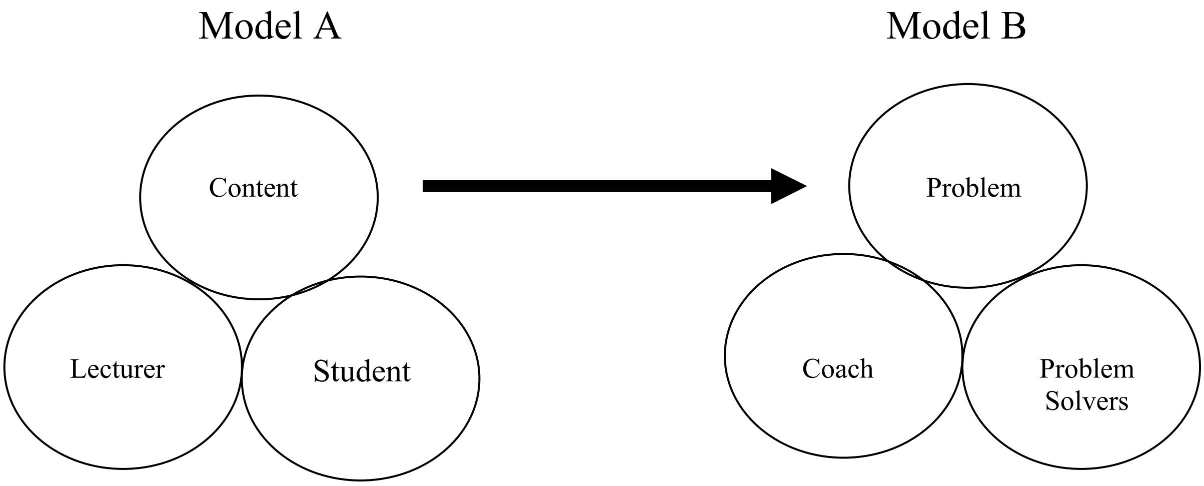
It was our belief that if we could improve the student's ability in these areas there would be a discernable positive result in terms of our objectives (O'Kelly & Gibson, 2005).

Handbook of Enquiry & Problem Based Learning. Barrett, T., Mac Labhrainn, I., Fallon, H. (Eds). Galway: CELT, 2005.
`http://www.nuigalway.ie/celt/pblbook/`

Course Design

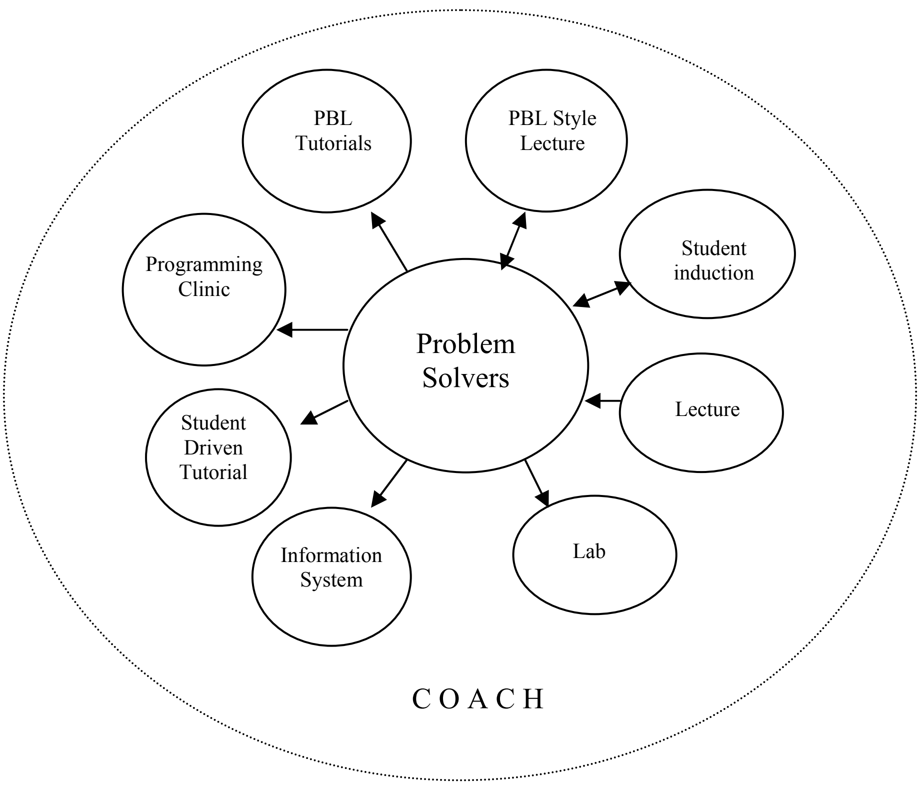
A curriculum shift towards Problem-based Learning is illustrated below:

Figure 1: Model of Curriculum Shift (Tan, 2000)



In the hybrid model, steps have been taken towards this shift, and resources added to assist the student in the transition from 'content push by the lecturer' to 'content pull by the student' as the problem solver, guided and supported by the coach (see Figure 2).

Figure 2: Hybrid Model of PBL



The major differences between the hybrid model used in this case study and the pure PBL model are: the duration of the problems, the continued inclusion of at least one lecture every week (PBL style lectures) and the methods of assessment (which include traditional exams). The remainder of this chapter describes each phase in the implementation of this hybrid model.

Staff Training

Problem-based Learning requires that instructors (in our case lecturers and demonstrators) adjust to the role of facilitator/mentor/coach (Woods, 1996). As this role is so critical to the PBL process, the post-graduate students, who all had previous experience of working with first year students, together with the lecturer participated in two PBL training courses, one prior to the commencement of the year and a second training course at the end of the first semester. The objectives for the first training course were to learn how to facilitate a PBL session and how to write a PBL problem. The second course allowed for reflection on the process and the objective analysis of the PBL implementation. These training sessions were organised and facilitated by Terry Barrett, an education development consultant specialising in PBL (O'Kelly et al, 2004a).

Student Induction

In addition to the induction programme run by the university, an alternate induction programme was run in the first week of term, specifically to introduce the students taking the programming module to each other and to the concept of teamwork. This was achieved during lecture time by organising the students into informal groups of three, and giving them puzzles and problems to solve collaboratively. Peer group critiques were also introduced to encourage students to be objective in their analysis of a given problem and solution. Groups subsequently presented their solutions and/or critique to the class. This type of interaction broke the ice and had students involved from the start.

In addition, during the lab time, students were placed into 'formal groups' and played a number of games which had specific objectives:

- 'Knowing me, knowing you' – the objective is for group members to get to know each other
- Pictionary - the objective is to reinforce the student's knowledge of their fellow group members
- Bridge Building – the objective is to introduce the idea of teamwork, communication and creative problem solving

The formal groups were then introduced to the concept of Problem-based Learning, the roles involved and the expectations for these roles and their designated workspace.

Problem-based Learning Tutorials

Our approach with the PBL tutorials is based on the work of Woods (1996), who suggests that you start where you are comfortable and with what is consistent with your academic environment.

At the beginning of the year every student in the class was assigned to a 'formal group' by the lecturer. Ellis and Dick (2000) argue that group size has a number of effects, including, the degree of participation possible, and the strength of bonds between members. Initially a group size of eight was decided upon, however, due to practical restrictions the group sizes ranged from five to seven on average. The constraints on the allocation of a student to a group were the time-slot the student signed up for (one of four different time slots) and the maintenance of a gender balance within each group. The gender balance was difficult to achieve with 62% of the class being male. However, where there was an imbalance, that is a lone male or female in a group, a balance was achieved by assigning a facilitator of the same gender to the group.

Each group was allocated a space to work in, a facilitator and resources such as whiteboards, flipcharts, markers, a set of props and a PBL journal. The PBL journal was comprised of two sections, the first section gave an overview of PBL and its evolution, explained and gave examples of team-building, critical thinking, brainstorming, the PBL tutorial, the roles involved and what was expected of each role, guidelines in solving problems, guidelines for group reviews, templates for team member contact information, templates for recording team rules and a glossary of terms for quick reference. The second section was updated on a week-to-week basis by the students themselves, this was to be a master record of their collaborative work during the year. Each team developed their own set of ground rules for behaviour and goal achievement, these rules were reviewed regularly by the team. It was the responsibility of each team to keep their journal updated. A team worked together for an entire semester.

Problem criteria and problem type

Ellis et al. (1998) argue that first-year students who are making the transition from a teacher-centred school environment to a more self-directed university environment may need the comfort of a well-defined problem with considerable scaffolding. However, PBL advocates the use of 'messy ill-structured problems'. The problems, designed by the lecturer and based around specific learning outcomes, fall between these two poles and take into consideration the following initiatives: each problem should be engaging, engender multiple viable hypotheses, allow enquiry, represent real-world problems, sustain engagement, provide accessible resources for subsequent learning and be based on current curriculum. The problems were subsequently discussed at a weekly meeting with the facilitators and any perceived difficulties were addressed (O'Kelly et al, 2004a).

The problems created fall into three broad categories; firstly, *extendible conceptual problems,* that is, problems that ensure the students focus on core concepts of computer programming in order to solve a problem. These problems involve no programming but require the students to understand programming related concepts. These problems also allow for increased levels of difficulty to be added to the problem once a solution is found to ensure that the problem sustains the student's interest. *Non-extendible conceptual problems* help a student to understand programming-related concepts without performing any programming. This type of problem has just one solution and is not extendible. *Programming problems* are typical computer programming problems that the group try to solve collectively. This type of problem aids the weaker student as he/she gets to see how a stronger student solves a programming problem (O'Kelly, 2004a).

Lecture Time

Waite et al. (2003) argue that if a student sits passively while difficult concepts are explained and they are told what is important (for the test), they are not taking responsibility for their learning. The previous approach employed in lectures began with the introduction of the syntax of a particular programming construct. This was demonstrated in isolation and later incorporated into a larger programme that solved a particular problem. It was found that students were able to understand the construct in isolation and recognise it in the sample programme but were unable to transfer this knowledge to their lab work. The alternate approach to lecture time is informed by the work of Deek et al. (1993), Woods (1996) and Waite et al (2003). A problem is presented at the beginning of class; the students are *paired* (informal groupings) and asked to generate possible ideas to solve the problem. Each pair of students is *grouped* with another pair and this group is asked to develop an algorithmic solution based on their combined ideas. The lecturer facilitates the group process during this period. The lecturer then collaborates with the students to solve the problem algorithmically with ideas generated from different groups of students. Once a solution to the problem is drafted, the lecturer then steps through the solution with the students, any difficulties are identified and rectified by the class and the step-through process begins again until such time as a viable solution is reached. At this point the translation of the algorithm to code occurs. During this process any programming concepts that students do not know are flagged. At least one of the lecture time slots each week is given to the theory and concepts behind the learning outcomes of the PBL tutorials in addition to the flagged programming concepts identified in the lectures.

Assessment

The method used to assess the students summatively remained unchanged. This allowed for a feasible comparison with previous year's results, in the knowledge that the only change instigated was to the course delivery. However, formative assessment of the student's performance in the PBL tutorials was introduced. Using a Likert type scale of 1 to 5, the facilitators rated a student's effectiveness in the PBL tutorial by their ability to support their beliefs, have effective communication skills, participate in the groups, be open to new ideas and show constructive critical thinking (O'Kelly et al, 2004b). Students were also evaluated on their fulfilment of duties in a specified role, for example, chair, reader, writer, and archiver. In addition, peer assessment and peer-group assessment took place.

What did the students think of PBL?

In order to assess this, a number of different methodologies were used to gather data throughout the year. An on-line student questionnaire, two paper-based student questionnaires and the interviewing of every group and 30% of the students in the class incorporating a broad mix of students, to ensure a fair representation of the class. The average return rate on the questionnaires was 78%, which gives a balanced reflection of what the students thought of the course.

Figure 3: Student feedback on the PBL process

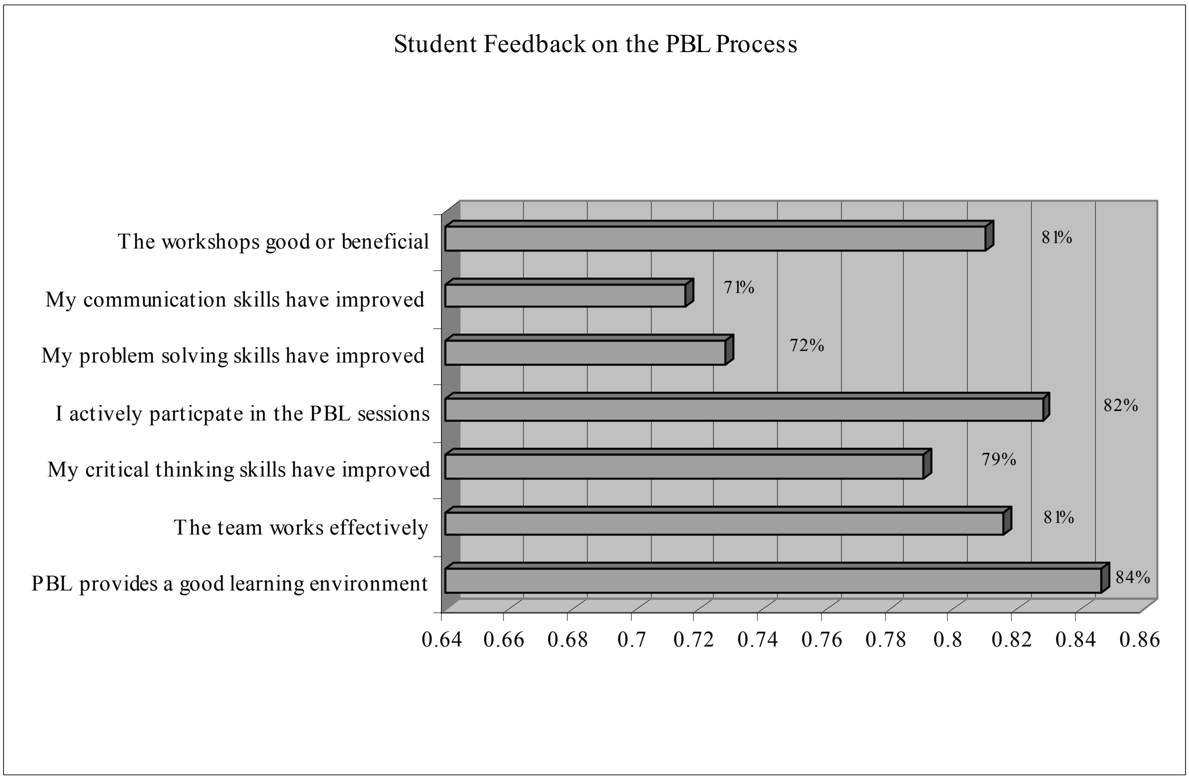
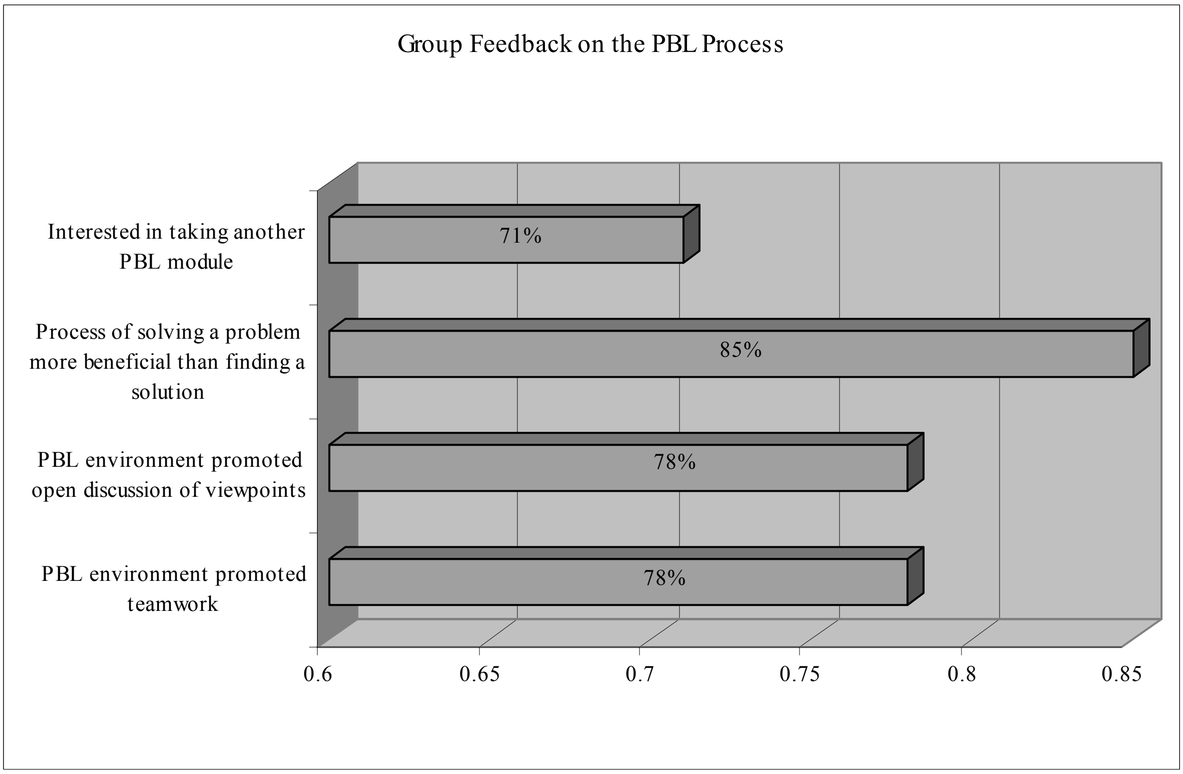


Figure 4: Group feedback on the PBL process



All mature students found the PBL tutorials and the interactive lectures provided a more interesting and challenging way of learning. Interestingly, the repeat students felt the PBL tutorials and interactive lectures helped to alleviate the feeling of isolation they had previously experienced.

Here are some written comments from students who thoroughly enjoyed the course:

> *Thanks for what was probably the most unique/different/interesting/involving subject I have ever taken. Don't change a thing for next year.*

> *PBL tutorials are the best way of learning because there are always different people with different ways to solve the one problem.*

Here are some written comments from students who did not like the course structure and would have preferred to work independently:

> *Just give me the problem and let me solve it on my own without having to negotiate with anyone else.*

> *Tell me the solution. Why are you asking me to do this when you know I cannot?*

In order to alleviate the latter frustrations, independent work was assigned in the labs and tutorials were provided to assist with difficulties in addition to the on-line scaffolding resources.

The results

The best indication of the success of the Hybrid PBL model is in the future performance of the students who took the module. Unfortunately, this information is not yet available. The next best indication is through making comparisons with the performance of students in previous years (O'Kelly & Gibson, 2005). By dividing the students into *poor* (bottom 1/3), *average* (middle 1/3) and *good* (top 1/3) within their class it was found that:

- Average laboratory performance increased for all students, with the *poor* students demonstrating the most significant improvement
- Average written exam performance increased for all students, with the *middle* students demonstrating the most significant improvement
- Overall performance (70% written exam, 30% practical work) – the normal distribution moved to the right, the change in standard deviation was insignificant

These preliminary results in conjunction with the student feedback look promising, however, in order to make any substantive claims a longitudinal study is required of first year students and the progression of these students through their undergraduate years.

CONCLUSIONS

The hybrid PBL model implemented provides a good transition for students to a university environment. The model has provided a framework to assist the students in problem abstraction, problem definition and problem refinement. It helps develop their critical thinking skills, their verbal and written communication skills and their ability to work in groups. It has also facilitated students developing peer group support networks that remove the feeling of isolation commonly experienced by first- year students.

A group size of 5–7 provides the flexibility for the roles in the PBL environment to be fulfilled without allowing room for freeloaders.

The transition from instructor to facilitator takes time. It is all too easy to fall back on old habits, especially when students are struggling with the problem. There is a need for facilitators to meet each week as a group to advise, assist, and support each other. In addition, continued training, particularly in the start-up year, is important.

There is a major difficulty in finding 'good' PBL problems in computer science; altering problems used previously in a course, by making them less prescriptive and by adding story-telling aspects that reflect real world situations is a good starting point.

Initial indications suggest that this hybrid model is facilitating a shift away from a surface learning approach. However, it is unclear as yet, how far along the deep learning path we have travelled.

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