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A Preliminary Investigation of the Role of Problem Based Learning (PBL)

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Abstract

Problem Based Learning (PBL) is a relatively recent innovation in education that appears to offer benefits that are not obtainable to the same extent by more traditional instructor-centred educational methodologies. This article tries to identify the key characteristics and benefits of PBL and asks how applicable they are to teaching computing at third level. The article is written as the first semester in which PBL was trialed in ITB draws to a close and is written from an active teaching rather than an educationalist research perspective.

Introduction

In recent years (since the mid 1970's) there has been an increased interest in Problem Based Learning (PBL) as an educational methodology which is not a instructor-centred as traditional educational methodologies. Education professionals are legitimately asking if PBL is applicable generally to most disciplines, and if so, should it be viewed as an alternative or a complementary methodology. Traditional teaching methodologies for technical disciplines place the instructor very much at the centre of learning for the student (with formal lectures, supervised laboratory work and tutorials), particularly in the early years of study at third level. A common view in education is that "assessment drives learning" and that "the curriculum shows you what the teaching staff are doing, assessment tells you what the students are doing"[1]. Current assessment methodologies at second–level can place more emphasis on knowledge recall rather than actual understanding and this experience can be reinforced at third-level. It may be unrealistic to expect learning not to be primarily driven by assessment, but better assessment methodologies may map the student's learning more closely to the course objectives. The careful specification of course objectives and the design of curriculum, learning and assessment methodologies to support them is a problem to which PBL offers a solution. It is not the only solution. This article represents a first step in trying to define what is meant by PBL and if it can be applied to the teaching of computing at third level in an Institute of Technology

Neither of the authors had any formal experience with PBL prior to the beginning of this semester but one had experienced a form of learning that appeared, on investigation, to have some parallels. This was in professional officer training in a military academy. The approach

taken to training young officers in command of operational units to deal with operational tasks in a fluid and often adverse environment is based on the assumption that it is impossible to train them to deal with every possible eventuality. Training therefore focuses on the development of a generalised set of competencies which can then be applied in any situation. More specific knowledge-sets and competencies are also developed on required (and fast-changing) specialisations, such as weapons control or logistics, but it is the core set of competencies that are reinforced throughout the professional military life in a series of courses and exercises of escalating responsibility and complexity. Another identifiable component of this training was that assessment is primarily based on previously on live exercises which mirror as close as possible, the real-life situations in which the officer will have to act. A number of observations were made based on this experience:

- This approach to training is first carried out with learners when they have just finished their second-level education, and therefore they are initiated at the same time as our students begin third-level education.
- The model of education where training objectives encompass both general competencies and discipline specific competencies seemed to have considerable merit
- The idea of using a method of assessment that tests for learning in the same environment and in which a learned has trained and using challenging scenarios as close as possible to the real-life working environment seemed to offer benefits.

This training experience is markedly different from the authors' own experience of other third level education and seemed to offer interesting possibilities for a more thorough investigation.

What is PBL?

There is no universal view or definitition of what constitutes PBL and there are different views and emphasis, depending on what is read.

Problem Based Learning is a teaching strategy for posing significant, contexualised, real-world situation and providing resources, guidance and instruction to learners as they develop content knowledge and problem solving skills.

(Mayo, Donnelly, Nash & Schwartz, 1993) [2]

PBL is both a curriculum and a process. The curriculum consists of carefully selected and designed problems that demand from the learner acquisition of critical knowledge, problem solving proficiency, self-directed learning strategies, and team participation

skills. The process replicates the commonly used systemic approach to resolving problems or meeting challenges that are encountered in life and career.

(Dr. Howard Barrows)[3]

In Problem Based Learning, you will spend much of your time learning – by identifying what you need to know, finding out, teaching each other and then applying your new knowledge. Thus, the primary aim of the exercise is the learning, not the completion of the project. The project is the means to this end.

(Dr J. Kaya Prpic and Dr Roger G. Hadgraft)[4]

Although different definitions of PBL abound, a set of common characteristics of a PBL educational approach can be identified[5] that includes:

- Using stimulus material to help students discuss an important problem
- Presenting the problem as a simulation of professional practice or a 'real-life' situation
- Appropriately guiding students' critical thinking and providing limited resources to help them learn from defining and attempting to resolve the problem
- Having students work collaboratively as a group … with access to a facilitator
- Getting students to identify their own learning needs and appropriate use of available resources
- Reapplying this knowledge to the original problem and evaluating their learning process

This approach is clearly different from traditional approaches, placing the learner at the centre of the education process and moving the teacher towards the facilitation end of the instructional spectrum.

Why use Problem Based Learning?

The rationale for considering the adoption of PBL must be firmly based on the desirability of its objectives its ability to meet these objectives. We will begin by briefly overviewing the objectives of PBL. A key aim of PBL is to assist students in achieving a set of core competences which can be generalised as follows:

- To adapt to a changing professional environment
- To improve decision making in unfamiliar situations
- To be able to critically analyse issues

- To be able to create solutions to certain problems
- To work effectively within a team
- To be able to identify strengths and weaknesses.

In order to be capable of benefiting from and coping with modern life, the student needs to acquire more than just a store of knowledge in the subjects that relate to their future profession. Students who embark on higher education now may still be in that active professional practise by the time they are 60 years old or later. They will need to be able to adapt to and participate in change within their professional environment. A key aim of PBL is to impart competencies for life.

A second aim of PBL is to develop effective conditions of adult learning. PBL seeks to do this by creating deeper learning and understanding through the students posing their own questions and simultaneous engagement with the broader curriculum in the context real-world problems, rather than on a course-by-course basis. This learning is carefully scaffolded through the use of a sequence of increasingly challenging problems to provide cumulative familiarity with the knowledge-sets and competencies as they are needed in real life. If these aims seem relevant, how can PBL lead to their achievement?

The PBL Process

Problem Based Learning is a system of teaching and learning where, without prior preparation, small groups of students consider an unfamiliar situation, problem or task. By exploring the nature of this unfamiliar situation, students share prior knowledge and experience. As the student progresses, they pose questions which they need to explore in order to progress with the task. After a period of individual study and research about the problem at hand, the student discusses what they have learned and how it relates to the original situation. In other words, using the normal approach to teaching, students are either taught or assumed to know how to solve the problem before they are given it, whereas with the PBL approach, the knowledge arises from working on the problem and trying to solve it.

Ross et al[1] developed a framework for problem-based curricula in 1985. In describing the initial framework, *et al* drew up distinction between different types of problem related curricula. They are as follows:

- **Problem-oriented Curricula:** Problems are used as a selection criteria for content of the course

- **Problem-based Curricula:** students work on a problems or scenarios as part of the course
- **Problem-solving Curricula:** students are trained in a process that helps them to approach a problem and create a solution

The possibility of a "hybrid" model, which can incorporate all three, seems an attractive approach. A framework overview for developing such a training model might be:

- Firstly, the design team selects a problem or scenario
- They use this problem to define an area of "knowledge" to be covered
- In relation to the problem, the team selects an event/scenario that will be given to the students
- A facilitator supports a core problem-solving process executed by the students where
    - The students must define the problem from what they have been given
    - The students must then express this problem as a set of questions
    - The students then use these questions to find out what resources they will need to use

This PBL process Model is a "guide" for the teacher/instructor on how the PBL framework could be implemented. It is divided into seven steps and it is aimed at Problem-based Curricula. This seven-step process was originally developed by the University of Maastrict in the Netherlands. Fig 1 shows a life cycle of this seven-stage process.

1. **Read and analyse the scenario or situation:**
   Students should check their understanding of the scenario

2. **List Hypotheses, ideas or hunches:**
   Students will have some theories or hypothesis about the cause of the problem, or may have an idea how to solve the problem, based on existing knowledge.

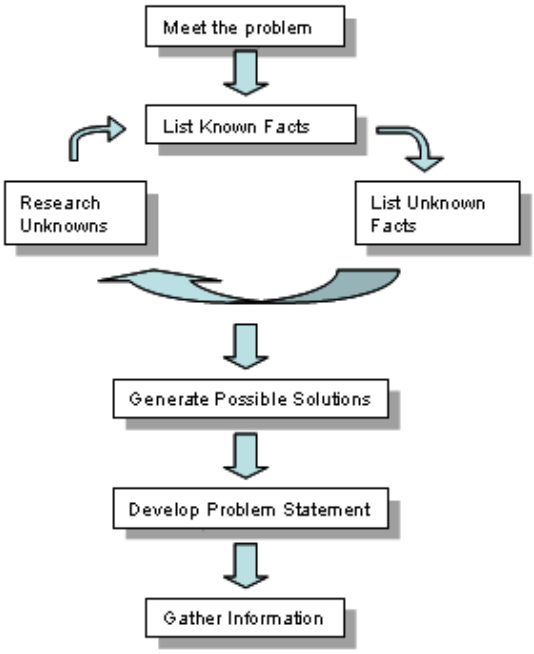

Fig 1: The seven-step process of PBL

3. **List what is known:**

   Students should make a list of everything that is known about the scenario. No research is necessary at this point. Using only prior knowledge and information included in the scenario, students should draw up some conclusions and ideas

4. **List what is unknown:**

   Students should now prepare a list of questions that need to be answered. Several types of questions may be appropriate. Some may address concepts that need to be understood before the scenario can be addressed, whilst other questions may request more information

5. **List what needs to be done:**

   Students need to plan the investigation, i.e. question a leading expert, visit a library, use the Internet to find answers to questions posed in step 4

6. **Develop a problem statement:**

   A problem statement is a one or two sentence idea what clearly identifies what the student is trying to solve or find out.

7. **Gather Information:**

Having completed the above steps, students will now need to gather, organise, analyse and interpret information from many sources. Students can exchange ideas, consider the pros and cons of each and as more information is gathered the problem statement may be refined or altered.

Once the above steps have been completed, the students (whether they are working in a group or individually) need to prepare some kind of report in which they make recommendations and can support their conclusions and solutions.

Are PBL objectives relevant for Computing?

If we look back at the set of generalized competences identified earlier we can clearly see their relevance to potential computer science graduates if they are to work in a professional environment such as software developers, systems architects/administrators, etc. There are of course more computing specific competences that would need to be added to meet the requirements of an undergraduate computing course, such as:

- To be able to read and write code, debug a program and execute a structured analysis, design and implementation of a software development project
- To be able to design, build, operate and manage an IT system
- To understand concepts associated with computing
- To understand how to apply computing concepts and techniques to provide solutions to real-world problems

Objectives such as these are currently addressed by traditional methodologies, typically on a knowledgebase/skillset basis, on a subject-by-subject approach. The combined application of these different subjects tends to only occur in project-based subjects and later in the third-level cycle rather than from the beginning. It is worthwhile to at least consider addressing them by using a more active adult learning approach than using conventional approaches only. For example, the teaching of programming in most third level institutions today consists primarily of students being given a lecture at the start of the week, followed by a tutorial class. The lecture introduces new topics and aspects of Java. The tutorial reinforces the information provided in the lecture but with higher interaction between the teacher and student. These activities can be largely passive on the students' part. The third teaching component involves exercising the student in applying the programming technique taught during the lecture/tutorial. Using the alternative PBL learning process, lectures are no longer the core means of imparting material to students. The process results in the students being given responsibility for their own learning from the beginning of the course and throughout. The emphasis is on the

'learning process' i.e. teaching the learner how to learn for themselves, rather than on an specific knowledge or skill. The role of the lecturer becomes one of facilitation and subject matter expert.

Core Issues in Using A PBL Approach

If PBL is worth trialling in a Computer Science environment, what are the main issues to be addressed?

Curriculum Design: The potential of PBL as an educational approach is highly dependant upon the design of the curriculum. It has been well researched that for a curriculum to achieve this, it must include the following aspects[7]:

1 ***Integrated Learning***

Subjects should be available for study as they relate to a certain problem or task and should not be treated individually

2 ***Cumulative Learning***

Subjects should be not studied in detail, but rather be reintroduced over and over again with increased complexity

3 ***Progression in Learning***

As the students mature, so should the various aspects of the curriculum

4 ***Consistency in Learning***

Students should be tested for application and understanding and not just recalling of knowledge.

Problem Formulation: The problem is all-important in PBL course design. Driven by the course objectives, the problem must stimulate, requiring the learner to engage with a range of knowledge and skills in a real-world context, while at a level consistent with the students state of development. While in our limited experience these don't seem to be radically different from current assignment or homework problems, they are broader in scope (involving knowledge/skills from a range of subjects) and mirror real-world problems e.g. the core problem trialled in PBL in computing this semester was the requirement to redesign and plan the implementation of an existing IT infrastructure to a more modern infrastructure that minimises the impact on the existing production architecture. An aspect of problem design is that it should be scalable in that, at the beginning of the year, a simpler problem is posed but it is important that it can be escalated or adapted to meet higher learning requirements. In this way, the problem serves as a vehicle through which the learner is exercised iteratively on the core PBL (self) learning process.

Assessment: Another key issue with using PBL is to establish objective assessment methodologies that are consistent with the learning aims. Although elements of traditional continuous or terminal assessment may be still prove relevant, assessment which involves real-world scenarios, or at least simulation of real-world scenarios, seems highly desirable as a measure of establishing the achievement of PBL objectives. This form of assessment should probably be proportioned more towards continuous rather than terminal assessment (dependent on the course objectives and real-world requirements).

Going Forward

This introductory discussion of PBL, coupled with our initial experiences, leads us to make a number of general observations:

- PBL seems to offer additional benefits to those provided by more traditional methodologies and therefore merits further investigation
- The general objectives of PBL seem to be relevant for the technical courses run in the Institute and appear to have the potential to prepare learners equally well for both industrial and research work.
- For students who have only experienced more didactic instructor led styles of learning, the PBL process offers a useful form of transition to the real-world where people work in teams and engage with contextually broad problems without initially knowing how to solve them
- PBL may offer an effective learning alternative for people already in the work place because it doesn't rely on attending instructor-led sessions as traditional methodologies. Instead, once the PBL process has been absorbed, it could lead to effective independent learning by learner groups. An added advantage would be that the emphasis on group interaction in PBL would leverage the experience of these people within the group, thus improving peer-learning opportunities.
- From an academic teacher perspective, the PBL methodology appears to be extremely consistent with an interest in research, insofar as the subject matter expert answers learner queries from their broad experience and current interest, rather than delivering 'set-piece' lectures.
- Although we initially approached PBL from a desire to improve retention, in our initial experience, we have identified that the PBL process is not for every learner. Some personalities are not suited to the central group dynamic and do not participate in the process. These learners fall into two groups – they are either already 'successful' independent learners who are happy to continue exclusively with their current

approach or else they are students who have a record of low performance and attendance in conventional classes.

Is Problem Based learning a better approach than traditional methodologies? We don't know, but it certainly is different. There is some evidence to suggest that in medicine at least, " for higher level courses, … research points to the fact that students schooled in problem based learning are better able to apply their knowledge of the clinical sciences and have better developed clinical reasoning skills than (traditionally instructed) students.[8]" We expect to continue our investigation into PBL over the next academic semester and are particularly interested in researching if the implementation of the core PBL process would benefit from the development of a generic suite of IT tools that would support key issues like course objective definition, curriculum design, problem formulation, the seven stage PBL learning process and learning assessment for any course to be delivered through PBL.

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