PROBLEM BASED LEARNING IN ENGINEERING

Patrick Walsh

Department of Manufacturing and Operations Engineering, Enterprise Engineering Research Group, University of Limerick, Ireland
E-mail: Patrick.Walsh@ul.ie

ABSTRACT
Educators and employers share a common goal of "educating/employing people who are highly motivated and who give 100% effort to their work". The main reason that this goal is not realised is because the people being taught/employed lack motivation. On the education side a lot of what is taught is not applied so the students cannot see the benefit of this learning. On the employment side the workers are not able to apply what they have spent their undergraduate time learning. What is missing? The link between the students' learning and industry needs. Problem based learning (PBL) seeks to addresses this problem. PBL is a teaching method in which students learn through solving a problem. This paper reports on how PBL addresses engineering education.

INTRODUCTION
PBL has different approaches in different contexts, given the academic, social, cultural etc. circumstances. The common philosophy is however to build and support a learning process established around engineering problem solving. Some approaches are based on minor problems integrated into individual lecture courses to illustrate the engineering applicability of the topic. Other approaches are based on solving major real life engineering problems with a few lecture courses given a supplement or background for this task [1]. For example, the mechanical department in Trinity University San-Antino, teach mechanical engineering using PBL and the problems that drive the curriculum increase in complexity as the student progresses through his/her undergraduate studies. PBL is a teaching method in which students learn through solving problems. The key features of PBL are :

1. Reliance on problems to drive the curriculum. The problem identifies the starting point and indicates what knowledge will be needed to solve the problem.
2. The problems are ill-structured. The problems have more than one right answer with a complexity that prevents a full understanding when first encountered. The problems change in nature as more is discovered about them.
3. The students assume a major responsibility for their own learning. Lecturers are coaches and facilitators. Most of the learning occurs within the context of groups rather than lectures.
4. Performance based assessment. The assessment is on how the problem is approached, knowledge identified and how the knowledge is brought to bear on solving the problem.

IMPETUS FOR CHANGE

The IET formerly IEE have identified that there is an impetus for change as employers are seeking graduates that know how to learn. Have the confidence and ability on how to tackle and solve real life problems. Employers want workers, who possess key transferable skills in communication, group working and interpersonal skills, able to get ideas across by presentation and with proficient information technology skills.

Dr. Carol Twigg, director of Pew Learning and Technology Programme states that "An overwhelming body of research shows that students do not learn effectively from lectures, and testimony from the field corroborates the literature". Pew charitable trust gave over $600K to the University of Delaware and a similar grant to Samford University in Alabama to investigate restructuring traditional instruction on problem based lines. They see the ability to solve problems is more than just accumulating knowledge and rules; it is the development of flexible, cognitive strategies that help analyse unanticipated situations to produce meaningful solutions. Real-life problems seldom parallel well structured academic problems. Therefore the ability to solve university based problems does little to increase the relevant, critical thinking skills that students need to interact with life beyond the lecture rooms.

Professor Jim McQuaid "Output Standards & Professional Body Accreditation" Engineering Professors' Council stated "Engineering teaching is based far too much on problems with 'right' answers and assessment based on the student getting the 'right' answer. The poor student is brought rapidly down to earth after graduation when he or she finds the real problems are characterised by insufficient information so that judgements have to be exercised". The PBL approach brings prior knowledge into play more rapidly and ends up fostering learning that adapts to new situations and related areas quickly in an enjoyable way. That is, people are enthused about being able to problem solve. Interest in PBL is growing not only does research show a higher quality of learning (though not a greater amount if amount equates with the number of facts), but PBL simply feels right intuitively. It seems to reflect the way the mind works.

In traditional education students are seen as external to the department with little to contribute. With PBL students are encouraged to contribute along with the educator; this is a step towards creating a new culture in University departments based on trust and respect for student contribution. In PBL students assume the role of 'workers'. If we are to apply Quality principles, then, as middle managers/lectures, we academics must pass responsibility to the workers – to the students [2]. Then the Deming 14 points about total quality management (TQM) can be applied to PBL.

	TQM	PBL
1	Constancy of purpose	A shared (negotiated) vision for the department is required
2	Adopt quality as a guiding principle	Management must be committed; changing academics is the hard part
3	Cease dependence on mass inspection	Reduce the number of formal exams; ensure quality rather than test for it; get it right the first time. PBL encourages the best work, rather than minimal effort
4	Do not award business on the basis of price tag	Choose a teaching method that maximises the benefits minus the costs – PBL may not reduce the staff time, but it could increase total output (e.g. publications)
5	Improve constantly	This is taken for granted in the research sector but with active student involvement, it could also happen at the undergraduate level; students could contribute to the development of resources for subjects
6	Institute training and education for all members of the organisation	It is essential that staff and students are trained to get the most out of learning by understanding learning principles
7	Institute leadership	Heads of departments must be leaders in teaching as well as research; this is probably the greatest weakness we have with appointments being largely based on research reputations
8	Drive out fear; build trust and respect	Trust and mutual respect will generate outstanding work for students. It is an essential part of PBL
9	Break down barriers between departments	Make undergraduate courses closer to the current research activities through PBL case studies, data analysis etc, and actively involve staff and students for other departments
10	Eliminate slogans	Slogans are replaced by trust and respect and recognition that much of what is wrong with student performance is a management problem
11	Eliminate numerical quotas	Work to eliminate restrictive numbers such as credit point restrictions and restrictive assignment requirements and deadlines
12	Ensure pride in workmanship	Team ownership is a natural part of PBL
13	Vigorous education and self improvement	PBL prepares students for lifelong learning
14	Take action	The problems lie with management; vision is required

Table 1: TQM and PBL compared [2]

HOW PBL WORKS

PBL works by having the problem develop the curriculum and different Universities use different methods to carryout the learning. But they all adhere to the key features outlined in the introduction.

As an example the following is the method used by the Department of Electronic and Electrical engineering in UCL:

- Small groups of students (usually no more than 8) work with a PBL tutor or facilitator.
- The groups meet twice a week, each time for around 2 – 2.5 hours.
- The students identify the main issues and formulate questions to work on.
- Following a period of individual study (2 – 3 days), the group reconvenes.
- They will discuss what they have learned, and apply the new learning back to the original problem.
- Supporting activities (labs, lectures) are timetabled as 'Fixed Resource Sessions" during the periods of individual study.

DESIGNING PBL PROBLEMS

The problems in PBL provide the force for learning by presenting a situation in need of resolution. Initial analysis of the problem pushes higher order thinking, recognition of areas where there are knowledge gaps. The solution requires search for new knowledge and understanding. The solution has more than one correct answer and requires the student interaction with other members of the group. This environment is where the student learns to learn. The problem context provides a framework for connecting new ideas with prior knowledge gained from experience. The problems relevance justifies the student's efforts to learn. The more applied the problem the more motivated the student will be. The shared quest by the group requires communication and promotes teamwork and interpersonal skills.

Effective PBL problems:

- Motivate students learning through real-world relevance
- Pose open-ended initial questions that encourage discussion
- Push students to identify and seek out needed information
- Complex enough to promote group effort in solving
- Requires decision making or judgement (development of higher-order thinking)
- Address course learning objectives

CONCLUSION

Thomas Cortes (when president of Samford University) interpreted PBL as "a newly recovered Style of Learning". In his view PBL embraces the question and answer dialectical associated with Socrates as well as the Hegelian thesis-antithesis-synthesis dialectic [3].

There are two major outcomes from University Departments, (1) graduates and (2) research results. PBL facilitates combining both of these outcomes. When the undergraduate students are working on real life problems the information they generate, by looking at problems directly may lead to conference and journal publications. This introduction to publication may also lead to further research within the University. To create an environment for this win-win scenario there needs to be a good dialogue between the University and Industry.

A case study by Fleming K. Fink about the implementation of PBL at Aalborg University, Aalborg, Denmark shows how establishing a University in a region with only little industrial activity can stimulate and, to a large extent, be the basis for a development of this region to an industrial community with world class competence [4].

Learning in context ensures retention in long term memory and ready retrieved in related contexts. PBL helps develop lifelong applicable competencies through a progression of PBL sessions. These competencies are what industry wants future employees to have and would prefer not to have the learning done on their time.

Incorporating PBL into the undergraduate curriculum is a challenge. However it is a challenge worth meeting in order to help students develop lifelong learning skills, such as problems solving skills and interpersonal communication skills. What student gains from PBL increases the job satisfaction of the educator/lecturer.

REFERENCE

1. Fink, F.K., How can we apply the Problem Based Learning Philosophy in Continuing Engineering Education? in 6th UICEE Annual Conference on Engineering Education. 2003: Cairns, Queensland, Austrailia
2. Hadgraft, R.G., PBL - a vital step towards a new work environment, in International Conference on Problem-based Learning in Higher Education. 1995: Linkoping, Sweden
3. Rhem, J., Problem-Based Learning: An Introduction. The National Teaching & Learning Forum, 1998. **8**(1)
4. Fink, F.K., Problem-Based Learning in engineering education: a catalyst for regional industrial development. World Transactions on Engineering and Technology Education, 2002. **1**(1)