Identifying Good Practice in the use of PBL to teach computing.

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ABSTRACT

This paper presents the findings of an initial study to identify the use of Problem-based Learning in the teaching of computing within higher education programmes. The study aimed to identify examples of the use of PBL, as well as examples of good practice and issues that needed consideration for successful implementation. Practitioners were surveyed in the UK, Singapore, Australia, Sweden and USA. The study found that the use of PBL in the teaching of computing does not appear to be widespread, but, where it was in use, a number of benefits were reported. These included improved student motivation, employability, student retention and pass rates. The paper also identifies a number of challenges that face implementers; and it includes some recommendations that may assist tutors wanting to use PBL within the teaching of computing.

Keywords.

PBL, Problem-based Learning, Computing, Curriculum

Introduction

Problem-based Learning (PBL) has been the focus of many developments in teaching and learning facilitation in recent years and many claims have been made for its effectiveness. It has been claimed that PBL produces independent learners who are motivated, engaged in deep learning, work as a team, and develop effective strategies, skills and knowledge for life-long learning and professional work. John Biggs also cites PBL as a good example of aligned teaching. (Biggs 1999)

Professional and funding bodies promote PBL as an appropriate strategy for professional education and it is increasingly becoming the method of choice. (Newman, 2003: 5)

Employability is also a term that has received considerable attention recently. It is often assumed that computing graduates score highly in this area, as a result of the vocational nature of the subject. However, employability is much more than possession of vocationally relevant skills and knowledge. For example, Peter Knight and Mantz Yorke have developed a systemic model of employability which incorporates an understanding of the discipline, skills of various kinds, efficacy beliefs and metacognitive fluency, and an awareness of how students act, learn and develop their capabilities. (Knight & Yorke, 2003)

They identify that "it would be worthwhile to build into curricula some form of bolstering of self-theorising and self-efficacy" and to concentrate on "control [of own learning], effort and learning" to promote *learned optimism*, rather than *learned helplessness.*(Knight and Yorke, 2002 p18). Graham Hendry suggests that the PBL tutorial process promotes the development of metacognitive skills. (Hendry et al., 1999)

Problem-based Learning provides a rich and complex learning environment, which provides considerable opportunity for students to develop employability characteristics. (Beaumont and Frank, 2003)

Some of these claims sound like the discovery of the 'Holy Grail' of Higher Education. They beg the obvious question: Can these claims be substantiated? In particular, can PBL be used successfully to help students learn computing?

A recent extensive pilot systematic review on the effectiveness of PBL highlighted considerable "conceptual, methodological and practical problems" in performing a robust meta-analysis, (based on published studies of PBL used in HE programmes for health professional education. Consequently results were inconclusive. (Newman, 2003, :8)

Models of PBL vary considerably, and a number of variants have been identified (Savin-Baden, 2000). Case studies of the use of PBL have been published (for example Boud & Feletti, 1997), although we have found very few case studies of the use of PBL within the discipline of Computing.

David Boud points out that "It is rarely possible to translate a given approach from one context to another without considerable modification" (Boud & Feletti, 1997:.11). The (professional) context of the subject discipline and knowledge base therefore has a fundamental influence on the way PBL is implemented. McCracken and Waters (1999) compare PBL problems in software engineering to medical school problems suggesting that there is a potentially significant difference between the problems in the two fields. Medical problems tend to be shorter with solutions consisting of a diagnosis and proposed treatment. In software engineering there are deliverables developed over a longer period of time and assessment of these is primarily summative. Computing is a wide-ranging discipline, and it is debatable whether PBL is suitable for all topic areas, for example in fields with formal mathematical semantics.

Implementing PBL also requires considerable change to the way student learning is managed and consequently there are risks. Within this study we tried to identify successful implementations and their characteristics to reduce the risks for anyone moving to PBL.

We have chosen to structure the paper around the '3P' model of a teaching and learning system (Biggs, 1999: 18). This model focuses on three points: presage (before the learning takes place); process (during learning) and product, (the learning outcome).

This model is useful at the macro level for PBL, allowing us to focus on factors before the trigger / problem is introduced to students, the process of Problem-based learning and the outcomes at the end of the PBL case. This 3P model, adapted for PBL is illustrated in Figure 1 below.

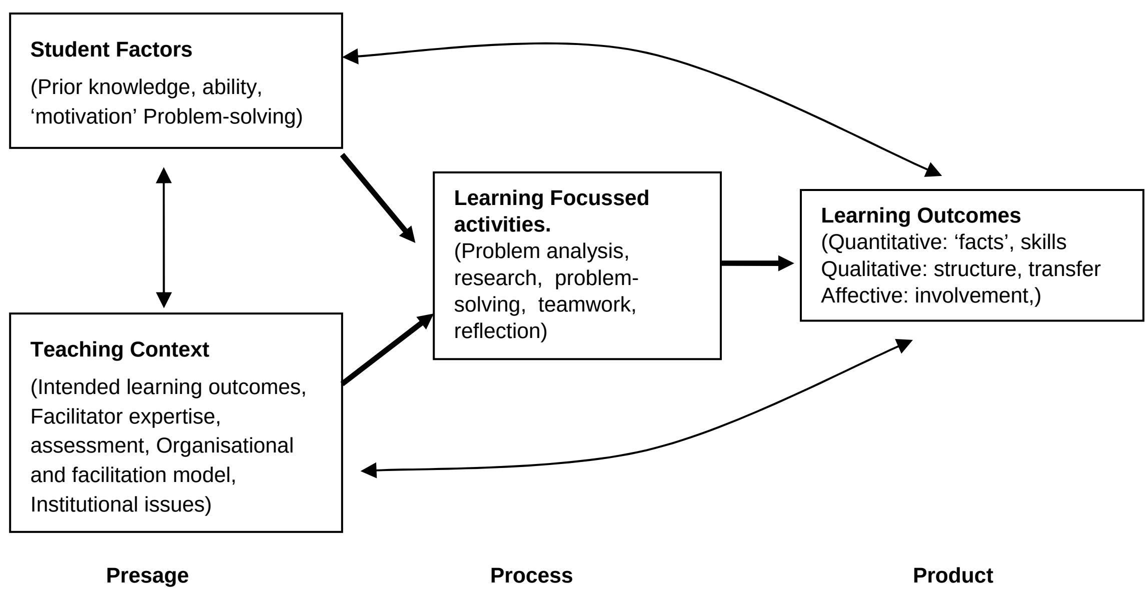

Fig 1: the 3P model, adapted for PBL.

Problem-based Learning

Problem-based Learning as it is conceptualised nowadays started in a number of North American medical schools in the 1960s and has gradually spread to other disciplines (Boud & Feletti, 1997). PBL has therefore evolved, and practitioners have adapted PBL principles to suit their own context. In this paper we do not intend to define any particular model as 'pure' PBL – indeed it would be inconsistent with our research methodology. However, it is nevertheless useful to provide some indication of characteristics that are shared by most models. Figure 2, illustrates a 'typical' PBL cycle.

a) Learning starts with a problem, question, or scenario to be investigated.(Macdonald, 2002) The problem is typically interdisciplinary and is related to the real world. Such 'real-world' problems are usually complex and are messy and ill defined. This situation promotes investigation on a number of lines and does not have one 'correct answer'. The key point in PBL is that the problem / trigger is introduced **before** the students know how to solve it. This distinguishes PBL from purely *problem-solving learning* in which students apply **existing** knowledge to a new situation. Thus, in the PBL setting, much of the knowledge needed to solve the problem has not been acquired, so students go through an extra stage: negotiating what they need to learn with their peers. This need to solve or manage the problem situation drives the learning. (Savin-Baden, 2000)

However in certain contexts, it has been reported that ill-defined, real world problems may actually discourage students instead of motivate them. For instance first year diploma students at the Temasek IT School are encountering IT as a formal discipline for the first time. In cases like this, an initial structured problem (complex problem broken down into sub-stages with clearly defined deliverables at each stage) helps ease them into the PBL setting. This "structuredness" decreases with every problem given to the students.

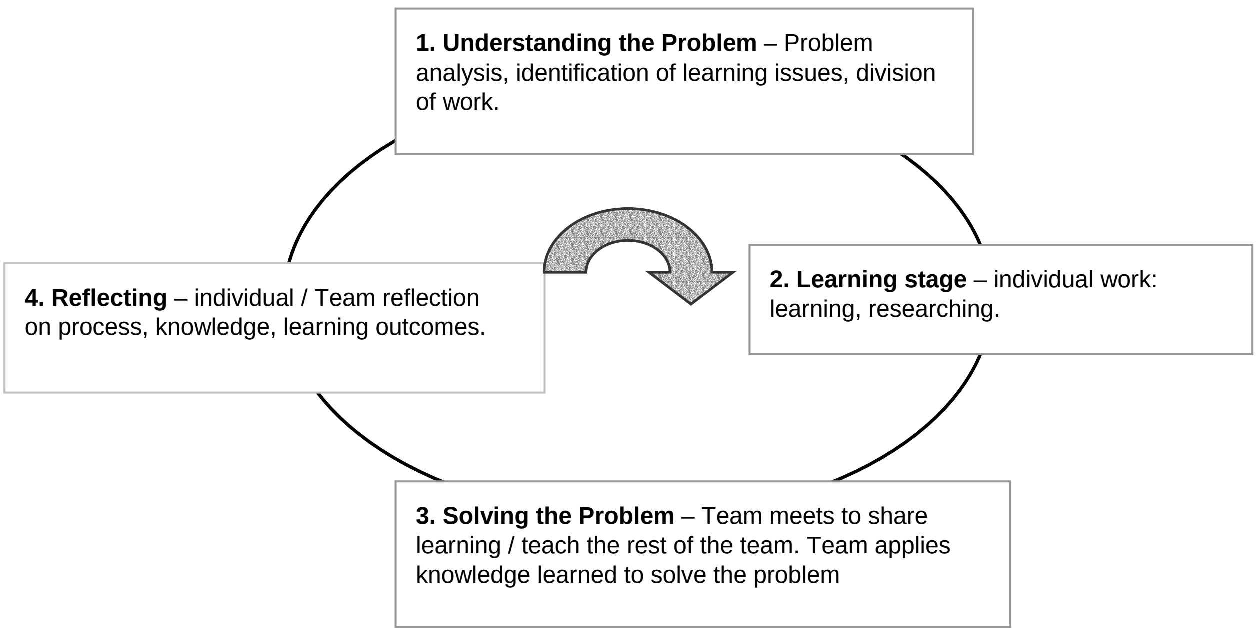

Fig 2: The PBL cycle

b) Students work in small, self-directed teams with a facilitator (coach). The facilitator may be dedicated to one team, or may rove between a number of teams. Facilitators may be faculty members or students, depending on the model. Teams may or may not have a leader. Student teams identify 'learning issues', research these individually and meet to share their results and present to each other how their research contributes to the problem solving process. Other team members are active by challenging or requesting clarification. Finally the team collectively applies its pooled knowledge to solve / manage the problem situation. This process can last from one session to an entire semester, and the process can be re-iterative, though multi-stage problems are often used over longer periods. At the end of the cycle students reflect on their learning and may engage in self or peer assessment as part of the overall assessment process. Self assessment at the start and end of the process can also be used to help students to reflect on their problem-solving strategies.

c) There is an emphasis on the process skills, critical thinking, reflection, promoting teamwork and social skills, at the expense of declarative knowledge. Don Woods states that this emphasis will utilise at least 20% of the curricular time (Woods,1996).

Barbara Duch and her colleagues provide an excellent practical handbook for implementation, which explains how a variety of models have been used. (Duch et al., 2001)

So how effective is PBL? Biggs draws attention to a series of surveys, which conclude that:

1. Both staff and students rate PBL higher in their evaluations and enjoy it more than traditional teaching.
2. PBL (medical) graduates perform as well and sometimes better on clinical performance.
3. PBL students use higher level strategies for understanding and self-directed study.
4. PBL students do worse on examinations of basic science declarative knowledge. (Biggs, 1999).

However, such simply stated conclusions mask a great deal of detail and there is a danger of generalising from this review. Much of the research reviewed was conducted with medical students in very well resourced environments. One potential limiting factor of PBL is that it is very resource intensive. Given the variety of models of PBL, limited resources in most HE institutions and the diversity of students, we need to question whether similar conclusions can be applied to the use PBL in teaching computing. Is PBL a good choice for teaching computing?

The suitability of PBL for use in the teaching of computing.

The vocational nature of computing and information systems disciplines has long been recognised by students and faculty alike, which suggests that the PBL approach may be suitable.

Ellis et al. suggest that “the computing discipline lends itself to PBL … in the following ways:

- Computing is, for the most part, problem driven;
- Life-long learning is a necessity due to the rapidity and continually changing nature of the industry;
- Practitioners must constantly update their skills and competencies in order to keep abreast of new technology;
- The project group is the predominant mode of operation within the industry; and

- Computing crosses discipline boundaries. "

(Ellis et al., 1998: 42)

The IT professional is thus constantly learning and solving problems. To be effective in this changing environment requires the professional to be able to constantly re-assess and modify their strategies. This reflection is built into the PBL process.

Bentley suggests that "the filling up of our students' brains with content may be at the expense of critical thinking and the development of other skills graduates require in the profession" [of Information Systems]. The knowledge base is important, but we need to be very clear on the justification and emphasis we place on the particular knowledge we select to include in undergraduate computing courses in view of the rapid development of the discipline. (Bentley et al., 1999:.1)

Similarly McCracken and Waters suggest using PBL as an approach to overcome the "instructional gap" between what is taught and what needs to be taught in teaching software engineering. (McCracken & Waters, 1999)

If we accept the claimed benefits of PBL outlined at the start of this paper, and the analysis that Ellis provides, then logic suggests that the PBL approach is very closely matched to the requirements for teaching computing.

Problem-based learning is not new, and was used in a Bachelor of Informatics degree at Griffith University (Brisbane) as long ago as the mid 1980s (Little and Sauer, 1997). Perhaps we might expect that it would be well established within Computing and Information Systems departments by now.

However the evidence from our survey suggests that this is not the case.

Research methods used in this paper.

The research was conducted in a number of phases:

a) A literature review was undertaken to identify published examples of PBL use in computing, possible issues / benefits and appropriate organisational models.

b) The identification of "PBL in computing" practitioners in the UK. Three approaches were used: email to the LTSN-ICS mailbase of over 80 institutions and direct mail shot to 50 UK computing heads of department at higher education institutions in Midlands/ North of England (Spring 2002). Additionally the Brighton[1] and Samford

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[1] Brighton categories searched were Computer Engineering and Computer & Information Science. http://interact.bton.ac.uk/pbl/

University[2] databases were searched, the latest search being made on 11 April 2003

c) The identification of "PBL in computing" practitioners in the USA, Sweden, Australia and Singapore. This was carried out via the Samford University, University of Brighton PBL databases, publications and UK practitioners' contacts.

d) On-line questionnaires were used to collect data, and were followed up with in-depth semi-structured interviews for UK and Singapore respondents. The questionnaire asked open questions to collect data on: the organisational model used, why PBL was selected, how PBL was incorporated into the curriculum, assessment, examples of triggers, advice for introducing PBL, issues in implementing PBL. The interviews explored these issues in more depth.

e) A 1-day conference was included to facilitate sharing of practice and discussion of issues and benefits (May 2002). A summary of the outputs can be found on the LTSN-ICS- Web site. http://www.ics.ltsn.ac.uk.

A qualitative approach was used at this stage of the research, to capture diversity and issues / recommendations that practitioners considered important. As indicated earlier, there are a variety of PBL models – PBL means different things to different practitioners. We left it to respondents to decide whether they considered themselves to be using PBL.

The use of PBL in the teaching of computing in the UK.

The response rate to our surveys was low. The mailshot / email yielded six positive responses (and two negative responses). The Samford database listed 32 UK institutions, two of which were using PBL in computing (26 were in medicine/Nursing, the next highest being Engineering with 3 institutions listed). The Brighton database listed 3 out of 51 UK institutions using PBL in computing. We found no publications describing the use of PBL in UK Computing or Information Systems teaching.

Within the UK there appears to be limited use of PBL in Computing and Information Systems. These instances were all in single modules, motivated by the enthusiasm of individual tutors. Examples include:

1.	Software engineering methodologies (undergraduate)	London Metropolitan University
2.	Computer Networking (undergraduate)	Edge Hill College of HE

[2] Samford category searched was discipline: Computer Technology yielded no results, each record was examined individually. http://www.samford.edu/pbl/where.html

3. Web Site Development (HND) — University of Derby
4. CBT development (undergraduate) — Staffordshire University
5. Network Construction and Administration (undergraduate) — Oxford Brookes University

International use of PBL in the teaching of computing.

Our literature review indicated use of PBL in computing in Australia, Hong Kong and Singapore. The database searches yielded the following:

	Samford database		Brighton database	
Country	Total PBL instances	No of Computing Instances	Total PBL instances	No of Computing Instances
USA	73	2	17	1
Australia	20	1	13	1
Sweden	2	2	1	1
Singapore	1	1	2	1

In the USA the Samford database showed 22 institutions for Nursing/Medicine, followed by Education (17) Science (16) and Engineering (8).

Examples investigated further are:

6. First year Computer Programming (undergraduate) — University of Sydney
7. Approximately half of the computing curriculum (Higher National Diploma level) — Temasek Polytechnic, Singapore
8. Used as part of 3 years within 4.5-year civil engineering programme in IT. — Linkoping University, Sweden
9. First year systems analysis and design. (undergraduate) — Victoria University of Technology, Melbourne

Case outlines for examples 2,3,5,6 can be found on the LTSN-ICS- Web site. http://www.ics.ltsn.ac.uk

Reported key issues & recommendations.

There are a wide variety of models used in implementing PBL. However, successful implementation of any variant of PBL requires careful consideration of a number of issues. The following is a summary of those that have been identified in literature and through survey, interview and conference workshop. We have incorporated recommendations within the discussion of key issues, rather than isolate them outside their teaching context.

Presage Issues

Student Factors

When students first meet PBL, it is usually quite different from previous experiences of learning, challenging their beliefs and often leading to frustration and confusion, and then anger, a state referred to as *disjunction* (Savin-Baden, 2000). This can arise from a number of sources where PBL conflicts with students' prior experience and concepts of learning. The role of the student changes in PBL from 'receiver of knowledge' towards active researcher. Students are asked to take responsibility for their own learning. There is a change in emphasis from factual knowledge to process skills and an explicit requirement to work as a team (rather than in a group or as an individual). Course designers need to take account of these factors in preparing students for PBL.

An example of student preparation workshop can be found at the Temasek IT School in Singapore where students entering PBL programmes are required to attend induction workshops (up to 5 hours). At these sessions, they learn, via experiential learning, about their own and their team members' work styles, negotiating and conflict management skills, how to give and receive feedback, time and stress management and problem solving skills. Central to these workshops is the emphasis on collaborative learning skills where they are taught to differentiate between collaborative learning techniques and "divide and conquer" strategy. It is the former with its emphasis on the process of negotiating and co-constructing knowledge that the workshop facilitators want students to acquire. In addition, another key element of these workshops is training students to be reflective learners. Throughout all the experiential activities in the workshops, there is always a segment at the end that requires students to think about the strategies they have adopted. This helps bring students to think at the meta-cognitive level, that is to think about their own learning and thinking processes, a skill that De Bono (1996) describes an effective thinker as having in his possession.

One successful method of accomplishing this transition to PBL, reported from Singapore, is to provide relatively structured problems in the first instance. Tutors monitor students' progress and adapt the scaffolding provided as students develop. This has also proved beneficial in assisting new tutors to adapt to PBL.

A necessary requirement for students using PBL is the ability to apply problem-solving techniques. It is often assumed that HE students have this ability, but this is not always the case – it is unlikely that they have been taught explicitly how to solve problems before HE. PBL provides an *opportunity* for students to develop problem-solving skills, but Don Woods points out that this does not mean that students will do so!

A recommendation is therefore that Problem solving needs to be taught when students are introduced to PBL. Don Woods provides numerous resources for this purpose. (Woods, 1994, 1996).

Teaching Context

Intended Learning Outcomes

PBL changes the balance of learning to emphasise process skills at the expense of knowledge. PBL can be adopted at a number of levels within a module but if we really value the process skills and assess them summatively then we would expect that this change of emphasis would be included in the intended learning outcomes for the module.

A further question where practice varies concerns whether learning outcomes should be revealed to students at the start of a PBL case. If learning outcomes are revealed at the start, students may use them as cues towards the solution of the problem. One medical school reveals the learning outcomes at the end of a case, and requires students to formatively self-assess their achievement against the learning outcomes (McCrorie, P. 2002, pers. comm. 30 October)

Assessment

Assessment within PBL courses is often seen as a contentious area. Traditional summative methods such as examinations can be seen as undermining the aims of PBL since they can encourage rote learning and often assess a ‘canon’ of knowledge - at some stage students take a strategic view and direct their learning towards the problem of passing the exam. This can also reveal itself when students worry if they have “*learned something in sufficient detail for the exam”.* Despite the above criticism, our survey found that examinations were often used to test declarative knowledge. In some cases the examination is based around the PBL case study, however, in other cases the examination was built into the module definition prior to PBL being adopted.

Further issues raised by Ellis et al. (1998) include the tension between creativity and assessment and the importance of evaluation and reflection by both student and course designer. For example, first year BSc Information Systems students at Edge Hill were concerned whether it was better to be ambitious and creative in implementing enhancements to a program (with risk of failure) or to take a safe, easy option.

Courses adopting PBL often use a variety of assessment methods; for example: presentations, demonstrations, posters, reports, and logbooks. Frequently, the PBL case is not the only aspect assessed.

Peer assessment is often used to judge contributions made by team members. Many students find this threatening. They are willing to accept assessment by faculty (as ‘experts’) but not by untrained peers. To deal with this concern, it is recommended that, careful consideration be given to the weighting of such assessment and students should be prepared for both the giving and receiving of feedback and interpretation of assessment criteria (Temasek Polytechnic).

Other recommendations arising from the survey, interviews and conference are:

- Assessment should be aligned with the learning outcomes and problems.
- Intermediate assessment is recommended prior to completion of the problem (if it is of any size).
- A reflective component is regarded as essential (possibly incorporating self-assessment).
- Assessment methods need to discriminate against team ‘freeloaders’.
- Some subjects have experienced difficulties with professional bodies regarding assessment in PBL schemes. It seems less of an issue in Computing.

Facilitation / coaching

Very often, students are not the only ones who are new to PBL. Teachers also have to change their role from the expert in control to the facilitator of the acquisition of skills and knowledge. Even for teachers who have a high level of commitment to PBL this is not easy. Facilitation (we prefer the term ‘coach’) is an active (but not directive) process and identifying how and when to intervene requires skill. Preparation and training of facilitators was stressed both in publications and our survey.

At the Temasek IT School, a typical staff-training workshop in PBL consists of a 4-day workshop with a full day devoted to a discussion of the theory of constructivism and collaborative learning principles. The tutors typically go through short 15-min information sessions before being invited to reflect on their own teaching strategy in the PBL classroom. Just as they aim to train students to think about their learning, tutors are encouraged at these sessions to be reflective practitioners. They are also asked to try out collaborative learning techniques with their colleagues at these workshops so that they are sensitised towards how their charges learn to work together. By getting acquainted with these techniques, they can then see how these can be translated to their classrooms to get the most out of their students’ group learning experiences. At more advanced workshops, tutors learn about facilitating techniques. Typical areas requiring attention for new PBL tutors include questioning techniques and understanding student sentiments.

Organisational model and issues

The original medical school model for PBL allocated one faculty member to facilitate a single PBL team. This is resource intensive and no examples of this were found within computing. The size of team used varied in our survey; the size was between 3 and 10 students (most commonly 5 or 6) and a faculty member was responsible typically for a class of 25 - 30 students. One benefit of faculty acting as 'roving facilitators' is that it enables them to identify common issues, then stop the class and present a mini-lecture or discuss questions, answers and learning issues for all teams. Other facilitation models include the use of support staff or students as facilitators to increase the facilitator / team ratio. (Duch et al., 2001: 41)

One respondent from the USA had dropped the use of teams altogether – principally because of the issue of freeloading – but had maintained the PBL approach (with individuals) successfully for a number of years.

Lectures were also included in a number of cases – either as a means of dealing with organisational issues (Sydney) or as a resource on request (Edge Hill), or where the module was a hybrid model of PBL, including some taught sessions alongside a PBL case (typically coursework).

Accommodation is a further consideration. A small group room ('base room') for each team provides an ideal environment. However, most Universities do not have such facilities available. It is possible for computer laboratories and classrooms to have furniture arranged to support group work.

All of the UK computing respondents had introduced PBL on their own initiative, rather than being driven from the top down. Institutional support had been limited. While this ensures that highly committed staff implement PBL, it places a large burden on them for preparation, implementation and co-ordination of any others involved. It also casts doubt on the long-term viability of PBL in those contexts.

Problem development

Moving to a PBL model requires considerable preparation and work prior to the start of the module. In our experience, this is greater than for traditional teaching methods. (Whether it *should* be greater is perhaps debatable) The design of a PBL case is critical, since all learning is derived from this source. Our survey and conference participants suggest that good triggers/problems:

- Are aligned explicitly with assessment and learning outcomes, since they must enable students to achieve the learning outcomes.
- Are close to real life and involve reusable knowledge and skills. Real-life problems can be particularly motivating.
- Will help develop students' metacognitive skills.
- Take account of the students' experience of PBL, i.e. novice students should be given relatively structured problems, and the scaffolding

can be reduced as students become more expert at collaborative learning and problem solving.

- Don't allow students to guess their way to an answer.
- Are interdisciplinary. The inclusion of an ethical dimension often helps.
- Accommodate a variety of learning styles.
- Are relevant locally or in the contemporary situation. Suitable triggers can often be found in the press, e.g. Computing / Computer Weekly.
- Should be accompanied by a facilitator's guide. The contents of the guide can identify appropriate learning outcomes, questions to be used as prompts, learning issues students are expected to generate and additional information that can be revealed when required (for a multi-stage approach).

Barbara Duch recommends that problems are ill structured and sufficiently complex to make sure that all team members must be involved. This ensures that a simple solution by "divide and conquer" methods shouldn't work. Academic rigour is based on *complexity*, not volume of information. (Duch et al., 2001: 48)

PBL cases can range from small problems that can be completed in one session to multi-stage problems covering a semester. Where PBL cases extend over long periods we have found that multi-staged problems work well, since this helps students to plan their time and keep motivation levels high. A useful technique in such problems is to reveal information progressively.

Developing good PBL problems is not easy. Barbara Duch provides details of a 3-stage approach; identify Learning Outcomes, real-world context and finally staged design. (Duch et al., 2001: 49)

Process issues

We have categorised the learning process activities as follows: Problem analysis, research, problem solving, teamwork and reflection. Within this process, issues were identified in teamwork, resources and facilitation.

Teamwork

Many students have poor experiences of working within groups. In order to work well, PBL needs students to work as a team rather than a group. The biggest difference between the two is commitment and accountability to each other, and in this context, responsibility for their own *and their team members'* learning. Mutual respect is essential, and the notion of freeloading doesn't exist. That's the aim. Teamwork starts with team formation.

Since teamwork is critical for successful PBL, sufficient time for team formation exercises needs to be provided. Our findings suggest:

- Teams don’t just form; they need active coaching and a clear purpose and performance ethic. Planning to include team-building exercises can help.(Woods, 1996)
- Students should not self-select their teams. Students are likely to self-select teams with very similar individuals. Since teams need a variety of personality types/ work orientations to perform well, self-selection can actually work against them. (Survey /conference)
- Students need to be clear of ground rules, and should set the team’s ground rules, including penalties. Some form of peer assessment of team participation is often used. A clear system will help reduce the occurrence of ‘freeloading’. (Duch et al., 2001: 62)
- Team size is very important, and should relate to the scale and complexity of the problem. Typical examples used in computing are 4/5 students per team. Larger teams can enable students to work as pairs on the learning issues. This reduces the reliance of the team on one individual, and can increase the reliability/ validity of students’ research results. (Survey/ interviews/ conference)

McCracken and Waters (1999) identified that students need explicit training in group dynamics, they tend to rely excessively on existing knowledge, and they focus almost solely on product-related issues versus process-related ones.

A further danger concerns the division of learning issues to individuals, and the requirement for those individuals to research and teach peers their findings. There are two prime risks:

Firstly the individual may not complete the research, or may not report valid findings. Able students are often unwilling to rely on others where there is this possibility. Allocating learning issues to pairs of students can reduce this risk.

Secondly, students may not be able to explain their findings and teach their peers effectively. “We are not trained teachers” as one Edge Hill student observed. One approach to avoid this problem (used in a medical school) required all students to research all learning issues and then share their findings. (McCrorie, P. 2002, pers. comm. 30 October)

Resources

Ellis et al describe a variety of PBL approaches to support learning within a range of cognate areas within the computing discipline. The paper presents an activity-based model, focussing on resources to support the activities, together with two case studies. (Ellis et al., 1998). The analysis of resources and tools is particularly useful in providing a checklist to assist the course designer. Resources are categorised as follows:

Resources to facilitate Group work	• Support communication and collaboration
Subject guidance and Information Access	• Reference • Searching
Resources to assist scaffolding	• Visualisation & experimentation • Problem-solving software

The Problem-based learning grid (PBLG) developed by Oriogun and Georgiadou (2000) can also be used at this point to assist course designers. It makes explicit the activities that stakeholders (for example tutors and students) would be expected to undertake within a learning event such as a presentation or a tutorial.

Facilitation / coaching learners

Coaching is the oil that makes the PBL learning cycle turn effectively. From a faculty point of view, this is often the most problematic part of PBL. Don Woods provides a detailed discussion of the role of the coach (Woods, n.d.). He identifies the following key behaviours:

- Ask leading and open-ended questions to help students explore the situation.
- Help students reflect on experience since this helps develop professional skill.
- Monitor progress, as it is a key component of problem solving.
- Challenge students' thinking to help students develop critical thinking.
- Raise issues that need to be considered, since groups without facilitators tend to identify only 60% of the teacher's intended goals.
- Stimulate, encourage and maintain a warm safe environment, enabling students to share and build trust. Students need to feel safe. They are likely to experience stress when introduced to the PBL process, associated with preconceptions of learning, teamwork and the open-ended nature of PBL. They need reassurance, support and resources making available.
- Understand both PBL and the subject and have an enthusiastic commitment to PBL.

Students may feel frustrated at the initial 'lack of progress'. Initial inefficiency is unavoidable as students adjust to PBL and team work. Any team goes through the same stages. The coach needs to help students to understand that these feelings are a natural part of the process.

Product Issues

The key issue here centres on how well students have achieved the intended learning outcomes. We acknowledge that there are validity / reliability difficulties, given the small nature of the sample, and consequently problems in isolating a single reason for any improvement. We present reported benefits and difficulties:

Reported benefits

Interviewees reported a number of specific benefits:

1. Improved attendance. (Over 95% in one example, and improved lecture attendance 50% to 80% at another).
2. Significantly improved pass rates and improved performance by weaker students. (Derby). Exam performance maintained (Edge Hill)
3. “There has been a substantial improvement in basic programming competence” in a first year introductory programming course. (Barg et al., 2000: 122)
4. Bentley reports improved time management, motivation, research skills, group work skills and problem solving. (Bentley et al., 1999)
5. Improved retention rates (dropout reduced from 15% to 5% for first years in Semester 1 at the University of Manchester Engineering Faculty). (Wood, N. 2002, pers. comm. 7-March)

Reported issues

Choi (1999) raises the issue of the risk of poor and limited solutions produced by students who are inexperienced at PBL. This reinforces the importance of preparing students for PBL.

A further issue that students have raised concerns the amount of ‘knowledge’ they have learned. They sometimes have a perception that they have not learned enough - although this is not shown by examination performance, where exams are used. Students tend to focus on the quantitative facts and knowledge at the expense of process skills and the affective domains.

Conclusion

We have identified a close match between the requirements for teaching computing and information systems and the features of PBL. PBL also provides a rich learning environment with opportunities to develop employability characteristics. Despite this alignment, there are surprisingly few examples of the use of PBL for teaching computing. All of the UK implementations surveyed have arisen from a commitment by individuals – a “bottom-up” approach, which casts doubt about their durability in the programme. The most extensive implementation (in Singapore) has centralised commitment and school-level dedicated expertise to assist development of cases, training of tutors and students.

Designing and implementing a PBL programme of study requires a radical rethink of the teaching and learning process, and is challenging for both faculty and students. There are numerous issues and risks to be overcome before a successful implementation, and we have outlined those and categorised them within the 3P model of learning and teaching. Categorising PBL in this way clearly identifies the high level of presage preparation that is required, changing the balance from a more traditional approach.

While the implementation issues are significant, all practitioners reported considerable benefits. Many PBL authors leave the impression that implementing PBL is an "all or nothing" decision. Our research has shown several successful examples where PBL has usefully been introduced into a single module.

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