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Introductory Systems Analysis and Design: a problem-based learning approach

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Abstract

Problem-based learning is one instructional approach that encourages students to become active learners and to take responsibility for their learning. This paper describes a trial of problem-based learning and its subsequent adoption in an introductory systems analysis and design subject with first year undergraduate information systems students. The paper raises a number of issues that arose for both staff and students. Some of the issues discussed include: a new approach to learning, design of teaching space, group work, assessment of process skills, attendance, facilitation and small group teaching, time and problem setting.

Keywords

Information systems education, Problem-based learning

INTRODUCTION

Problem-based learning (PBL) is an approach that encourages students to become active learners and to take responsibility for their learning and it has a strong basis in cognitive learning theory. Furthermore, Fogarty (1998:1) characterises PBL as "learning in its most authentic state. It is the real world. More specifically, PBL is an elegant design for learning that begins with an ill-structured or open-ended problem scenario". Biggs (1999:71) states that the objectives of PBL are "to get students to solve problems they will meet in their professional careers – the teaching method is to present them with problems to solve; the assessment is based on how well they solve them." The characteristic of PBL then, is that the problem scenario is presented to the student before any relevant theory or practice is given. PBL turns around the traditional approach to teaching and learning of theory first followed by practice, whereas the PBL approach is, problem first followed by theory and practice. Hence students are engaged in a problem within the context of their discipline, which in turn drives the motivation to learn and apply appropriate theory. Students work in small learning teams, bringing together collective skill at acquiring, communicating, and integrating information in a process that resembles that of inquiry (Barrows and Tamblyn, 1980; Woods, 1994; Savery and Duffy, 1995; Delisle, 1997; Fogarty, 1998; Savin-Baden, 2000)

PBL is an approach that has been used successfully in disciplines such as medicine (Boud and Feletti, 1991; Savery and Duffy, 1995). However the PBL method has not been meaningfully adopted in information systems education to the extent of fully integrated courses, as in medical disciplines. There has been some use of PBL in individual subjects in computing education and extensive use of project approaches such as the incorporation of a final year project in many information systems courses. A recent search (August 2001) of the Association for Computing Machinery (ACM) digital library of its journals and proceedings, reports only 8 articles that have the phrase "problem-based learning" in either the title, abstract or article text. Thirty-four articles were listed when using "problem based learning"; however, some of these articles are not related to computing education or are not addressing the PBL approach specifically, many articles are only a partial match.

The reason for investigating alternative approaches to undergraduate education in the School of Information Systems was the observation of students' difficulty undertaking final

year projects. Many students exhibited the problem of compartmentalised learning (subject based) and struggled to integrate previous learning to apply to a significant project problem. This raised concerns with the curriculum committee and the need to address students' learning. Most of the teaching and learning is teacher-centred and subject-based, the dominant mode being lecture-based delivery using the two-hour lecture and one-hour tutorial/workshop model imposed by the Faculty. In a traditional approach to teaching there is an emphasis on students acquiring knowledge, rather than the development of critical thinking and the problem solving skills required of an information systems graduate. What we have is essentially a behaviouristic, psychometric approach to learning and assessment. Jones (1990) suggests this leads to unrealistic workloads for students and may be intellectually unchallenging, encouraging passive learning that is unlikely to motivate many students. Lecturers in the School of Information Systems have attempted strategies to enhance student outcomes, but these are often isolated, individual efforts that, while laudable, probably do not encompass a broader curriculum perspective. Hence, there must be a better way to develop graduates more suited to the practice-based, project-oriented world of the information systems professional. PBL is one approach that might offer a match between curriculum delivery and the professional information systems work environment. Savin-Baden (2000:15) suggests from the PBL literature that there are four key reasons to adopt PBL: 1. develop student's reasoning skills; 2. enable learning to take place within a context that is relevant to the students; 3. ensure that learning is attuned to the world of work; and 4. promote student's self-directed learning abilities. Bentley *et al*. (1999a) discuss curriculum issues relating to information systems education and consider whether there is a better way to educate information systems students to ensure they become the 'compleat graduate', suggesting that a student-centred learning approach such as PBL may offer a better way. Also McCracken and Waters (1999) from a software engineering standpoint suggest PBL as an approach to overcome the 'instructional gap' between what is taught, and what needs to be taught. PBL may lead to a closer alignment between the teaching and learning approach used in undergraduate education and the work of an information system professional, with the outcome being a graduate better equipped to work in professional practice.

The School of Information Systems commissioned an exploratory trial of problem-based learning in 1999 and problem-based learning was adopted in 2000 as the philosophy of teaching and learning for the Introductory Systems Analysis and Design subject. Further teaching and learning goals emerged in accordance with university teaching and learning policy: to develop life long learning skills, for students to be active rather than passive learners and to create a learning environment that builds a sense of student identity with their course. Within the subject the aim is to encourage students to assume more responsibility for their own learning.

The potential benefits of PBL are: facilitation of integration of various disciplines; structuring of knowledge for use in IS contexts; development of effective IS reasoning processes; development of self directed and life long learning skills; enhanced student motivation through the challenge of real world problems; and, simulation of future professional practice and promotion of a holistic approach to IS and problems (Boud and Feletti, 1997).

Teaching and learning approaches can be considered as a spectrum from teacher-controlled through to student-controlled (Figure 1). An example of teacher controlled learning is the typical lecture and tutorial approach. Student controlled learning, at the other extreme, may be seen when students source and select a project that is relevant to their learning outcomes, area of interest and profession. A masters or doctoral research study may represent student controlled learning.

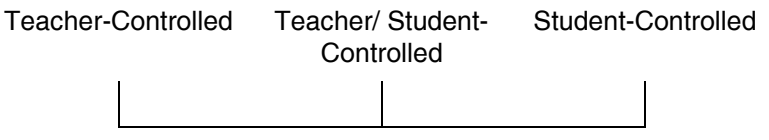

Figure 1: Spectrum of teaching approaches

The PBL approach to teaching lies somewhere near the middle and possibly slightly to the left on the spectrum. Most students in the subject have only experienced teacher-directed learning and need to develop the skills to manage self-directed learning. As it was the first time for both students and tutors in using PBL it was felt best to lean slightly towards teacher direction. Perhaps in later years the move towards greater student-controlled learning can be made and this change is probably best tackled as a gradual process. In the approach at Victoria University, the teacher set the problems, and then the students were responsible for how they solved the problem and what they had to learn. This approach is defined in the working papers of ITiCSE (Ellis *et al*., 1998:47b) as guided PBL.

METHODOLOGY

This study used a qualitative approach to understanding PBL and action research in refining the approach to PBL. A phenomenological research approach as described by Patton (1990) and Leedy (1997) was undertaken to understanding the student's perceptions of PBL. The initial study sought to understand students' perceptions of the effect of problem based learning as an approach to learning. Student perceptions were obtained from face-to-face interviews, focus groups, tutor observations, student emails, subject evaluation forms, and examination of diaries and planning sheets. Individual interviews were conducted with PBL students. This is consistent with Leedy's view (1997:162) that a phenomenological approach "typically involves 5 to 10 in-depth interviews". Each in-depth interview was approximately 45 minutes in length. The data collected was analysed, for shared themes, experiences, key words, and phrases.

The characteristics of the PBL approach used, benefits, challenges and issues arising are discussed in the sections that follow.

COURSE STRUCTURE AND TEACHING USING PBL

Initially a trial of PBL was conducted in semester 2, 1999 in the first-year compulsory subject "Introduction to Business Systems Development". The adoption of PBL as the primary teaching and learning strategy for 2000 and 2001 followed. The teaching using PBL is summarised in Table 1. The limited trial within a single subject allowed the lecturer to become familiar with PBL and learn how it could operate in an information systems subject. The lecturers' skills in PBL were gained by attending workshops, reading (especially the work of Woods (1994; 1996; 1997)), subscribing to PBL and education list servers, and visiting the Basser Department of Computer Science at the University of Sydney.

Year	PBL	Timetabled classes	Learning aids and information sources
1999	Trail of PBL	1 class PBL (self selected), 1 normal. 1-hour lecture, 2-hour tutorial	PBL Information session (trial only) PBL handouts. Subject expectations. Internet, Intranet, self-assessment tests, discussion server and e-mail, textbooks and libraries. Weekly planning sheets and diary entries. KNDA Planning sheet. Mini-lectures
2000	Adoption of PBL	2 PBL classes. 2-hour tutorial, 1-hour lecture, 1-hour group meeting	
2001	Continuance of PBL	1 PBL class. 2-hour tutorial, 1-hour lecture, 1-hour group meeting	

Table 1: Teaching using PBL

The PBL problems are sourced or adapted from real examples, though well structured to provide clues and 'scaffolding' to guide the students in their learning.

The subject is timetabled in the handbook as a one-hour lecture and two-hour tutorial/workshop in a computer laboratory. The small class sizes and delivery format have allowed some freedom to experiment with PBL. However, this may have implications for the introduction of PBL into other subjects if the current delivery model is used. The class times are scheduled to allow students the opportunity to meet regularly and spread their learning out across the week (Monday, Wednesday and Friday). A small campus timetable permits this, though it may not be possible on a larger campus and with large student numbers.

Tutors select students into groups based on their academic performance in the previous semester to achieve an academic balance in the group. The groups generally consist of five members. The groups are instructed that they are a learning group and will be together for the whole semester. A greater bonding relationship is observed amongst these groups than was seen in the trial where there was experimentation with groups.

Students complete weekly planning sheets to guide their learning. Students submit weekly reflective learning diaries (Appendix 1) where they record their reflections on their learning and activities related to the subject.

Students' expectations of the subject, their tutor and their own responsibilities are discussed and agreed to between the students and the tutor in the first class. These are placed on the web site. When issues arise, such as lateness or attendance, the expectations are used to remind individuals of the responsibilities they have agreed to. Through this process it is felt there is 'ownership' by students of these expectations.

A KNDA planning sheet is used to aid in the understanding and tackling of a problem. The KNDA has columns representing: What we already Know, what we Need to know, what tasks we need to Do, and who the task is Assigned to. This sheet is refined from a KWL (Know, Want, Learned) Chart in Barell (1998:35) and a KND (Know, Need, Do) Chart in Fogarty (1997:6). Using the sheet, students define the problem statement, goals and constraints; this assists students in scoping the problem. From the KNDA planning sheet students develop their own individual learning plan for the week(s).

Assessment in the subject includes the process of learning to some extent, as well as the content learning and outcomes, but there is a need to further address assessment in the subject.

Table 2 shows the schedule of problems over the 13 weeks of the semester. Large problems, which are termed 'assignments', involve a number of weeks. Smaller problems are completed in one week. The first problem was used to introduce the PBL approach to students. The smaller problems were interspersed between the large problems to reinforce the learning approach and overcome the mid-semester motivational lapse that students often experience.

Week	Problem	Nature of the problem
1	Problem 1	Understanding systems and roles
2 - 5*	Assignment 1	SDLC, analysis modelling techniques
6	Problem 2	Feasibility and project selection
7	Problem 3	Data gathering
8	Problem 4	Joint application design
8-13**	Assignment 2	Methodology, requirements specification and prototyping

*Week 5 includes a presentation to the class and reflection on the problem.

**Week 13 involves a presentation to the class and the client, followed by reflection.

Table 2: Schedule of problems

After reflection and discussion of the solution to a problem, a 'mini' lecture is often given. The timetabled lecture is also used to present material regarding topics that related to the student questions or comments from the previous week's planning sheets and diaries.

BENEFITS

The benefits perceived by both staff and students have been reported and elaborated in Bentley *et al*. (1999a). These benefits include: increased motivation; improved problem solving; improved time management; improved self-directed learning skills; improved research skills; and, improved group work skills.

Students suggested that the problems are realistic and relevant to the work of an information systems professional. In the trial there did not appear to be any appreciable differences between students' assignment and exam performances, though the groups were too small to make any valid statistical comparisons. The improvements in students through PBL was noted in the 2000 class by a tutor, who in the previous semester taught programming to the students, and who subsequently had the same students in a PBL class, confirmed the increased enthusiasm and motivation shown by students in their group work and approach to learning.

In improving self-evaluation skills, students probably for the first time in a subject, had to write down their reflections on their learning in their diaries. Early in the semester their diary entries indicated the need to spend greater time on reading and practice and to consider the number of hours spent on the subject. Many students realised the necessary commitment required for effective tertiary study as the semester progressed.

ISSUES AND CHALLENGES

Many issues and challenges arose in the teaching of PBL. Major issues in the subject were: a new approach to learning; teaching space; group work; assessment of process skills; attendance; facilitation; small group teaching; time; and, problem setting. Other issues from a student perspective arising in the trial (Bentley *et al*., 1999b) included: A focus on factual knowledge; problems with group work participation; weaker students requiring more direction; and, preparation and motivation for PBL.

Some of these problems and possible solutions are now discussed.

New approach

This is a new approach to learning for the students. The first 4 weeks emphasise teaching about the PBL approach. It is observed that students have to unlearn their prior conceptions of learning. Some students, especially the weaker ones, find responsibility for self-learning difficult and require extra tutor time in directing what they need to do and constant pushing to achieve a satisfactory solution to the problem. These students require reassurance that they are learning content as well as learning process skills as a valuable component of the subject. The ITiCSE Working Papers (Ellis *et al*., 1998:52b) state, "A key issue in professional development is to have the skills of self-evaluation and the ability to steer one's activities". The students had issue with fact that they were uncertain as to whether they were learning anything. Self-evaluation and reflection on the problem for students is achieved through the use of diary entries, presentation and discussion of the solution, discussion in the group or together as a class, and setting a written question for another group to answer. This question allows groups to demonstrate their learning. Weekly self-evaluation tests, consisting mainly of 20-30 short answer and multiple-choice content-based questions are given to students. Students report these tests help confirm their learning and provide pointers for follow-up learning if they identify a knowledge gap. In PBL there is a new role for tutors as facilitators or guides to empower students, Russell *et al*. (1994:59) suggests "educators are therefore required to implement strategies which promote self-directed learning skills, are conducive to students' construction of knowledge, and promote reasoning skills". The challenge for many lecturers in information systems will be to change their philosophy of teaching and learning from passive learning to using active learning strategies.

Introducing PBL into the second semester of first year probably means that students have already framed their perceptions of university education by undertaking subjects in their first semester that consists solely of traditional lectures and tutorials. It might be better to introduce PBL, or elements of PBL, in semester one for commencing students so that they can perceive that university education is different and not necessarily focused on content learning. Also this will help to develop student's self-directed learning and collaborative skills gradually throughout their first year and give lectures the opportunity to introduce and become familiar with active learning strategies.

Teaching space

Consideration has to be given to the design of teaching space to support PBL. Group work in computer laboratories caused difficulty, as the room arrangement did not allow for students to interact well as a group. There were few tables where students could sit around and have face-to-face discussions. Some groups sat in a line facing computers. When this was observed, the tutor discussed with students the means of creating an effective meeting space that encouraged face-to-face interaction and opportunity arose to discuss the dynamics of meeting as a group. Subsequently the group was observed to employ better meeting tactics. Fortunately there were free classrooms opposite the computer laboratory that students utilised from week three of the semester in 2000. This extra classroom is not a resource that universities can usually sustain. If PBL is to be adopted as the major teaching approach then consideration needs to be given to the teaching space and arrangement to support PBL group work.

Group work

A number of important issues regarding group work arose, including leadership, composition, and meeting times. Group leadership was addressed through the use of a rotating chair or team leader on a weekly basis, which ensured that everyone in the group had at least two weeks as leader. The leader chaired meetings, acted as a communication facilitator and checked other team member's progress during the week.

Formation and composition of groups can have an impact on a student's learning. The teacher selection of semester-long learning groups, based on their demonstrated academic strength in the subject from first semester, gave better balance to the groups than in the PBL trial. This structure seemed to allow peer pressure from the motivated higher-achieving students to encourage other students to achieve the tasks required. However, at times this resulted in students having to resolve conflict, decide on the level of the task suitable for each person and face real team issues about contribution. The knowledge that they were to be together for perhaps the whole semester seemed to engender a greater sense of group commitment and motivation, whereas in the trial, group formation changed a few times during the semester and often formed through self selection. It is felt that putting together a longer-term group fosters a team environment, though the problem of students moving between subjects in the first four weeks of semester needs to be addressed if groups are likely to shrink or be augmented by new members. This has not been a problem on the smaller outer campus but would need to be addressed in subjects with large enrolments.

Attendance

Attendance, both at class contact time and at group meetings, is crucial in this format of PBL. Marks were rewarded as an incentive to maintain attendance and participation. The poor attendance by members at meetings outside of regular class times was a major group work problem reported by students in the trial. As a result of student suggestions from the trial, an unsupervised laboratory hour was timetabled into the subject in 2000 for students to meet; this provided them with a common time and little excuse not to attend. Though student reported in 2001, "we have weekly group meetings, however not all members turn up".

The issue of time and group work arose. Students were concerned about the time they were spending on preparation, meeting time, reading and completing plans and diaries. This had

an impact on students, as many are employed for more than 15 hours per week to provide for their university education. The completion of what students saw as administrative tasks seemed to encroach on their time. One student commented, “administration takes more time than the learning”. The tools to aid and reflect on learning were seen by some students to be a burden that is not encountered in other subjects. This particular comment was addressed in lecture time to the whole class and helped to reinforce the change in learning they were encountering and the need to for them to develop new skills in “learning how to learn”. The student who made this comment had not submitted a planning sheet or diary in the first three weeks, and withdrew from the subject due to increased hours of part-time work, but had the commitment to stay with this group and assist in completing assignment 1.

Problem design and development

Setting and developing the PBL problem was an issue. There was uncertainty about the nature of the problems set, and consideration was given as to whether the problems were PBL or represented situation-based learning (Russell *et al*., 1994:61). It was felt that many of the problems perhaps lay somewhere between the two. McCracken and Waters (1999) compare PBL problems in software engineering to medical school problems suggesting 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, so the students can then move onto the next problem. In software engineering, however there are deliverables developed over a longer period of time and the assessment of these is a substantial part of a student’s grade. Explicitly setting the learning objectives for each problem seemed to assist in scoping the problems, so solutions and learning were achieved within the time limitations imposed by subjects. However the problems were not fully written up as a PBL case ready to be given to another tutor or shared at this stage. Extra curriculum development time needs to be found to do this. In a large subject this would certainly have to be undertaken in order to convey the problems to the tutors. The problems need to be authentic and presented as such, rather than being task-based or project-based. Perhaps with wider discussion of the development of PBL problems in the computing community, examples of appropriate problems may help to develop a norm for problems that lend themselves to PBL.

Academically weak students

Academically weak students, and in some cases groups of weak students, can be left behind and are likely to exhibit only surface learning. This has been the case in this subject as it is on an outer campus where students of a lower entry standard are directed and this presents a challenge for the academics. Characteristically these students are in the middle to lower level entrants to university courses. Weak students need to be pushed, and motivated by external rewards and punishment, whereas deep learners may be intrinsically motivated (Conrick, 1994:250). In PBL it is important to identify weaker students and to provide them with encouragement and feedback. In the trial, three students clearly identified that PBL was not an approach that suited them. They wanted more direction and structure imposed on their learning. Two of these students decided to undertake Technical and Further Education courses in 2000 rather than higher education studies. The weakest students strongly suggested that they preferred directed learning. Specifically, they desired resources such as set tutorial questions and expressed the need to be pushed or forced to do the work. An unintended consequence of PBL may be a self-realisation that assists students in identifying the approach to learning that suits them and whether they wish to be professionals or technicians in their computing career path. The challenge for the teaching staff has been the extensive time required to constantly push, feedback and support the weak students.

CONCLUSION

This paper has presented the approach, experience, benefits, challenges and issues of PBL in an Introductory Systems Analysis and Design subject. The use of PBL is at an early stage in the School, though the initial experience offers promise for improving students’ learning

and eventually better graduate outcomes. The next step is to introduce PBL into other information systems subjects, with a long-term view towards integrating a PBL curriculum across the information systems specialist subjects. The direction is likely to see the promotion of interaction between students and information systems professionals, through the use of real problems. Future work will be to examine assessment and perhaps place more reliance on peer evaluation and self-assessment as maturity in PBL is developed.

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APPENDIX 1

Reflective Diary Questions

1. What new thing(s) have you learned in the past week?
2. What reading have you done in the past week?
3. How well did you follow your individual plan for the week?
4. What was good about your planning and how could it be improved?
5. How do you feel the group work is progressing (towards problem solution)?
6. How could group interaction be improved?
7. What have you contributed to the group in the past week?
8. On a scale of 1 to 10, how confident are you currently feeling (in terms of your knowledge and skills) about:

   a) Microsoft Access

   1 2 3 4 5 6 7 8 9 10

   b) Strategies for systems analysis and design

   1 2 3 4 5 6 7 8 9 10

   c) Systems development techniques (data modelling and process modelling)

   1 2 3 4 5 6 7 8 9 10

   d) Data gathering and fact finding techniques

   1 2 3 4 5 6 7 8 9 10

   e) FAST methodology

   1 2 3 4 5 6 7 8 9 10

   f) System documentation

   1 2 3 4 5 6 7 8 9 10

   g) Project management

   1 2 3 4 5 6 7 8 9 10
9. Other comments or things you wish say (optional)
10. About how many hours outside of the tutorial did you spend on activities related to this subject in the last week?

    Less than 1 1 2 3 4 5 6 7 8 9 10 11 12 or more hours

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