INTEGRATION OF INFORMATION TECHNOLOGY IN THE PROBLEM-BASED LEARNING PROCESS

Cynthia Lim

Diploma in Law & Management
Temasek Business School.

This paper examines the integration of technology in Problem-based Learning (PBL). It explores what is being taught in PBL and how it is taught in the light of information technology (IT) advances. It also discusses how IT has improved learning in PBL under the constructivist theory of learning. Future implications for the use of IT in PBL will also be considered.

INTRODUCTION

The availability of Internet resources coupled with the different mediums of electronic communication have greatly altered the way collaborative inquiry in the classroom is carried out today compared to years ago. The advent of computer-mediated learning has created new possibilities in the way IT can be used in a PBL curriculum. This paper looks at what is being taught and how PBL is taught in the light of IT advances. Using the four stages of the PBL problem-solving process, the paper discusses some examples of how IT has been creatively integrated into the PBL curriculum to improve teaching and learning. The paper also highlights some limitations of and issues arising from the use of IT in PBL and considers the future implications of IT advances for the way PBL is conducted.

PROBLEM-BASED LEARNING

PBL is an instructional approach that uses ill-defined real-life problems as the impetus for learning (Boud & Feletti, 1997). The analysis of these problems results in acquisition of discipline knowledge and problem-solving skills (Uribe, Klein & Sullivan, 2003).

In PBL, the student is presented with a problem situation before he acquires content knowledge for the subject. Working with others, he analyses the problem, formulates learning issues and questions, conducts inquiry and research, creates hypotheses and reaches a solution to the problem (Barrows & Tamblyn, 1980).

The curriculum of a subject that utilizes PBL methodology can optimize the use of computers in collaborative inquiry, especially in the light of increased accessibility of knowledge through the Internet. Advances in IT have also ushered in new possibilities in the way PBL is used.

WHAT IS TAUGHT?

The goals of PBL are manifold. They include acquiring, structuring and fostering application of knowledge, learning the heuristics of the discipline and developing effective problem-solving, reasoning, self-directed learning, collaborative skills and increasing motivation for learning. In view of the different goals of PBL, what should teachers emphasise? Students' acquisition of content or process skills? Depth or breadth in content coverage? PBL practitioners often find themselves caught in "content versus process" and "depth versus breadth" dilemmas given the limited time and resources within the curriculum and the many goals of learning. Although the introduction of IT has helped to achieve some of the above-mentioned PBL goals, it has not helped to solve this dilemma. In fact, the use of technology may add to the cognitive demands of learners (Ochoa, Kelly, Stuart & Rogers-Adkinson, 2004) and the demands of a teacher's classroom time in having to prepare students to learn with computers.

Studies have shown that PBL promotes in-depth understanding of content (Hung, Bailey & Jonassen, 2003) but this is usually achieved at the expense of the breadth of content coverage. Adopting a PBL curriculum requires downsizing content coverage since it is not realistic to design problems that span the entire syllabus. PBL supporters believe that content acquired today may be obsolete tomorrow and since knowledge is rapidly expanding, no curriculum can fully cover the breadth of any discipline. Advocates of PBL favour the "less is more" approach of concentrating on fewer topics to allow greater possibility of rich connections and in-depth learning (Marlowe & Page, 1998).

This view is shared by proponents of the process skill curriculum who argue in favour of the importance of the processes of problem-solving, critical thinking and learning to adapt to change. However, one must guard against the danger of students not acquiring an adequate and well-structured knowledge base. An emphasis on process skills at the expense of content may lead to core concepts being overlooked or receiving cursory attention, and students lacking a sufficient knowledge base to use the acquired process skills for further learning. Without a sufficient knowledge base, they may not have anything concrete to "process"!

PBL does not deny expertise or content; rather it places content in an active perspective. Students learn in the context in which knowledge will be utilized in future (Engel, 1996). The use of IT has the potential of increasing efficiency in the use of classroom resources, thereby expanding the scope of coverage of both content and process skills in a PBL course. However, IT does not

replace the role of the teacher in deciding the competencies and outcomes to be realized in the PBL curriculum and what to teach in the course. The teacher has the task of achieving a satisfactory balance between process and content as well as depth and breadth of coverage.

PBL lessons are increasingly being conducted on course management systems such as WebCT and Blackboard. It is important for students to be taught how to use these systems, and such systems must be made a focal point in the course so their use and place in the course becomes familiar (Van Eijl & Pilot, 2003). The author encountered some resistance from students (who were unfamiliar with online learning) when her teaching team first introduced the use of Blackboard to support PBL a few years ago. These early experiences have taught her the importance of having students initiated into learning in online environments and developing the habit of logging into Blackboard on a daily basis from the start of the course. In the author's experience, the use of structured oral and online debates in small-group settings in a face-to-face classroom is an effective way for students to learn how to participate in discussion threads. The face-to-face sessions helped them overcome their initial apprehension of participating in online forums.

Experiences with collaborative learning using IT have not always been positive (Hathorn & Ingram, 2002). It is therefore important that students are prepared to learn online in any learning approach involving computers.

THE USE OF IT IN THE PBL CURRICULUM

The activities performed by students in PBL are constructivist in nature. Based on their prior knowledge and experience, students construct their own goals for learning (Arts, Gijselaers & Segers, 2002). They also engage in questioning and investigation as well as making connections between facts to construct their own meaning in the information gathered and applying it to the problem at hand. This section shows how the use of computers enhances the constructivist attributes of PBL.

The use of IT can expand the learning environment beyond the classroom and the teacher and promote active and independent learning. Besides opening up access to new information and experiences, IT can also enhance the quality of teaching and learning. In her seminal work on online learning in higher education, Laurillard (2002) makes a pedagogical analysis of what IT can offer and puts forth a convincing argument for the use of IT to improve the teaching and learning process. Some researchers have reported findings that using IT in a collaborative learning environment have led to higher achievement, higher level reasoning, frequent generation of ideas and solutions and greater transfer of learning in problem-solving performance (Uribe *et al*., 2003; Arts *et al*., 2002).

Looking at the various stages of the PBL process (represented in Figure 1), the paper examines how PBL practitioners have used IT creatively in the curriculum to improve teaching and learning.

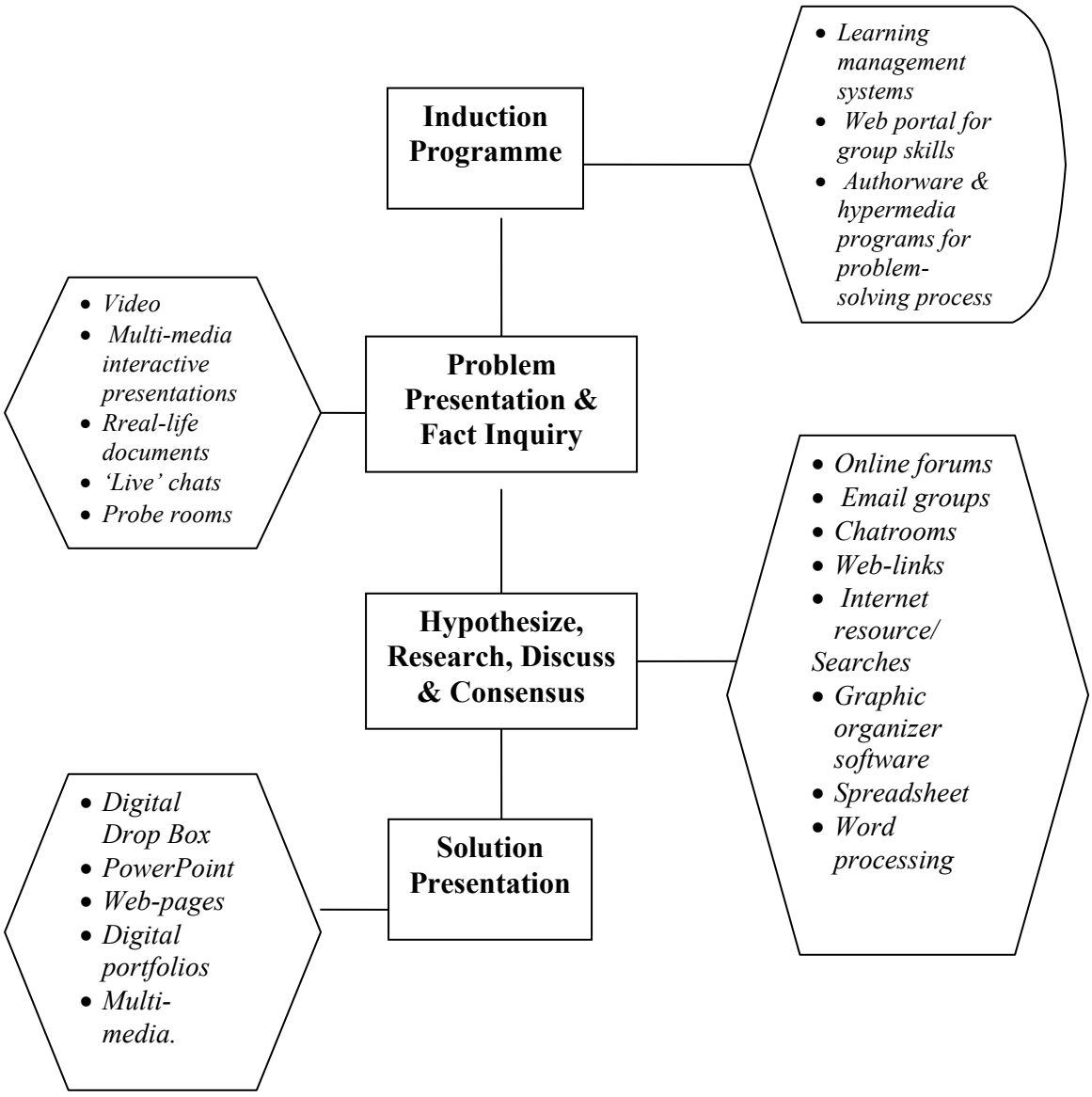

Figure 1: How IT has been used in the PBL process.
Chart adapted from Tan (2003, p.123).

Stage 1 – Induction programme

An induction programme is essential for students encountering PBL for the first time. Problem-solving skills and process must be taught (Uribe *et al*., 2003), especially to younger students who may have limited self-directed learning skills. They may become overwhelmed when encountering an ill-defined problem and the need to conduct their own research for the first time (Liu *et al*., 2002).

Through a course management system like Blackboard, instructions and guidelines, including assessment criteria, may be posted on the Web for students' easy access. Aside from information dissemination functions, some PBL practitioners have used instructional programmes as part of the induction process for students to learn process skills at their own time and place. Uribe *et al.,* (2003) report using Authorware to design a four-step problem-solving interactive Web-based induction program with an animated cartoon character showing students how to apply each step and allowing students to practise on their own. Martin (2004) used a hypermedia generic problem design to introduce law students to a legal problem-solving and decision-making process. Similarly, the School of IT in Temasek Polytechnic also designed a stand-alone web-based portal which hosts an interactive collaborative group skills programme to prepare students for group learning (Chew & Beaumont, 2003).

The ways in which each individual prefers to access, interact with information and construct knowledge is unique. As such, the design of the abovementioned interactive and dynamic IT environments using hypertext mediums like multimedia and hypermedia allow individual students control of information and pace of learning. Such environments also encourage students to learn how to solve problems through exploration and inquiry (Jonassen, 1992).

The use of IT at the induction stage can save labour-intensive training time and resources for teachers. It can also increase access for students who can participate in these activities at their own time and pace.

Students learning together in small groups in PBL form small "learning communities". It may be wise at the induction stage for them to have some 'live' contacts rather than only "virtual" contacts (Van Eijl *et al*., 2003). Using Kolb's experiential learning cycle to explain the life-cycle dynamics of a small group setting, a group of students coming together for the first time needs to go through the "forming and norming" process in order for them to work effectively in a collaborative setting. As such, it is suggested that some face-to-face contact time for team building should be factored into the induction stage. Although IT can enhance the induction phase, it should not replace face-to-face contacts between students and teachers entirely (Chew & Beaumont, 2003).

Stage 2 – Problem presentation and fact inquiry

One of the key strengths of PBL is the use of real-life problems which students can identify with to drive learning. Video recordings, "live chats", multimedia animation and asynchronous interviews have been used to present the problem to students.

In the *Alien Rescue* PBL environment (Liu, Williams & Pedersen, 2002), information on a science fiction rescue operation was presented through multimedia formats to allow dynamic and interactive presentations that address different learning styles and student needs. "Expert scientists" demonstrating (by thinking aloud) scientific problem-solving processes and a "probe room" for fact inquiry were used to provide a scaffolding and guide student learning through a cognitive apprenticeship model. These tools supported learning activities in large classes that would otherwise not be possible if students were left on their own.

In the area of special education teacher training, Ochoa *et al.,* (2004) presented qualitative results on the instructional usefulness of a PBL module where Web-based multimedia was used in three phases: from the problem presentation stage using video narratives and role-play planning and decision-making stage right through to the problem-resolution stage.

Face-to-face interviews supported by online "live chats" with clients, real-life documents such as student assignments, attendance notes and minutes of meetings, client emails and letters have also been used in the problem presentation and fact inquiry phase. The author was involved in a project where teachers designing a PBL problem left deliberate information gaps during the problem presentation and students were required to conduct online fact inquiry interviews/probes with their clients for missing facts.

In order to make the probe realistic, tutors pretending to be clients took on a certain personality. The "clients" became impatient and incoherent during probes so that students could experience some inherent problems in dealing with difficult clients in real-life situations. Asking good questions is an important skill in the problem-solving process. Through such simulations, students learn how to carefully craft their questions and treat their clients with respect and tact. In this project, probes conducted by student teams were viewed online by other students in the course who learnt vicariously from each other. Through viewing other team's probes, students could see different perspectives of the problem, co-construct new knowledge and benefit from the collective intellect of the entire class (Fisher & Coleman, 2002).

Liu *et al.,* (2002) reported that the use of IT as an interactive medium during this phase has led to increased student engagement and motivation in learning. However, production of high quality multi-media tools is time and effort consuming. If schools have a policy of not allowing teachers to repeat the use of their problems, then each problem will be used and presented only once and it may not be practical in such instances to produce a one-off video or multi-media programme. On the other hand, methods like role-played online client interviews can be used for a variety of problems.

Stage 3 – Formulation of problem statement/hypotheses, research, discussion and reaching consensus

Online discussion forums, web-links, internet collaborative inquiry activities and graphic organizer software are some of the ways IT has been employed at this stage of the PBL process.

In *Alien Rescue,* a virtual international space station containing information-gathering instruments and cognitive tools allowed for sharing of data among students and supported them in hypotheses generation and testing (Liu *et al*., 2002).

Vygotsky's theory of social constructivism defines learning as a social activity where learning is constructed as a result of interaction and shared efforts to make sense of new information. The use of the tools mentioned above gives students a new way of collaboration and co-constructing new knowledge in a social and educational space where resources reflect real-life learning.

Arts, Gijselaers & Segers (2002) report significantly improved scores amongst students and a higher level of interaction amongst students when PBL web-learning was introduced, leading to more in-depth elaborations of concepts and better understanding of the subject.

Xun and Land (2003) suggest that guided peer interaction in online communication and discussions could also be an effective scaffolding strategy to support learners in information processing and knowledge construction. Through guided peer interaction, students challenge each other to new perspectives and tutors can model, scaffold and monitor learning to help students accomplish more than they could on their own (Liu *et al*., 2002).

Stage 4– Solution presentation

Besides the use of Blackboard's Digital Drop Box feature to hand up students' written solutions to the problem, Powerpoint, Web pages, digital portfolios, computerized knowledge maps and multimedia presentations have been effectively used to present the solutions for the problem. The author and her colleagues have seen students use Web pages, MindMaps™ and multi-media creatively to support their oral presentations of the problem solution. Care, however, must be taken to ensure that students avoid spending too much time and effort on the aesthetics of the presentation, in the process neglecting the formulation of a cogent solution.

The advantage of using IT for solution presentation is that the work of various PBL groups can be easily viewed by other students, and all can benefit from the collective intellect of the class. Peer review and feedback can also provide powerful learning opportunities in a collaborative and social constructivist learning environment.

LIMITATIONS IN THE USE OF IT IN PBL

Whilst IT can be seen to enhance learning in PBL, it may also have negative effects if the teacher is not mindful of the limitations of its use in PBL situations.

The World Wide Web provides many opportunities as well as challenges to the young researcher. It may thus be necessary to teach and guide students to harness the potential of the use of the Internet. The information explosion on the Internet has increased access to available information for students conducting an inquiry. This increased access provides an opportunity for students to develop critical thinking skills in evaluating online resources. Students should be taught to defend the credibility of their sources of information in the course of their investigations (Chang, Sung & Lee, 2003) since there is a danger of obtaining inaccurate information through unreliable websites. Without appropriate guidance, inquiry learning may turn out to be more of a hurdle to learning for students and thus, a well designed and tested system for computer-supported inquiry learning will benefit both students and teachers (Chang *et al*., 2003).

Chang *et al.,* (2003) lament that there is a shortage of appropriate software for inquiry learning. For inquiry learning to be effective, there is a need to strengthen the explorative learning motives of students. Also, mechanisms to assist content exploration should be established to aid students

to compile and organise the information found online. Graphic organizer software like MindManager and Inspiration could be used for students to compile and organize data, but more IT software should be developed to support exploration and inquiry online.

Students engage in a fair amount of group brainstorming whilst formulating hypotheses and ideas leading to the solution of the problem. While PBL teachers have used online forums for brainstorming exercises, research on brainstorming has pointed to the negative effects of group interaction on the generation of ideas (Arts *et al*., 2002). Arts *et al.,* suggest that group interaction should only take place after individuals have completed their thinking in a problem-solving setting. Following this argument, one wonders if asynchronous brainstorming (where students have more time to think before typing their answers) is more effective than synchronous brainstorming.

Groups of people working together may not necessarily collaborate. If collaboration is a learning objective, it must be taught. With the use of the Digital Drop Box facility to share ideas and research, there is a danger of the final solution of the problem looking more like a patchwork of individual input rather than creating a new, unique and collaborative product (Hathorn & Ingram, 2002). Some PBL practitioners have used peer teaching and face-to-face discussions to ensure equal participation and individual accountability in collaborative work.

Discussion forums have been widely used in PBL but they may not be the best platforms for a group to reach consensus to a solution. Unlike face-to-face interactions where participants can draw on a whiteboard or pass slips of paper back and forth, simple text-based communications technologies may not allow participants to effectively work together (Hathorn & Ingram, 2002). Asynchronous forums also take longer to come to an agreement compared to face-to-face interaction and thus, it is important to use the appropriate technology for the task. Some tasks are better done face-to-face.

CONCLUSION

Much of the learning in PBL arises from students' pursuit of information that they determine they need. Thus, self-direction is crucial to the development of habits of life-long learning. The integration of IT has had a significant and positive impact on the way PBL has fostered collaborative inquiry and self-directed learning. The use of IT in PBL has also opened up more opportunities for online collaboration within schools, between schools and the industry. However, the PBL practitioner faces an ongoing challenge to realize the benefits as well as the limitations in the use of IT in PBL and to use the appropriate technology to positively affect the way PBL lessons are conducted.

How will the PBL curriculum evolve in the light of further IT advancements? Will there come a time where it is common to see PBL courses being conducted entirely online? The use of IT can greatly support PBL in achieving its pedagogical potential. As long as we remember to strive to use IT to enhance effectiveness rather than to replace everything with it (Chew & Beaumont, 2003), we should be heading in the right direction.

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