Paper prepared for presentation at the annual meeting of
The American Educational Research Association, Montreal, April 2005

Integrating Learning Technologies and Problem-based Learning: A Framework and Case Study

Prof. Dr. Philip Hallinger

Executive Director

College of Management

Mahidol University

Email Correspondence: Philip.h@cmmu.net

Keywords: Problem-based learning, learning technology, simulation, higher education, instructional technology

Abstract

Problem-based learning (PBL) and learning technology represent two of the most important trends in teaching and learning that emerged over the past two decades. PBL developed in response to the need for education that increases the retention of learning, fosters transfer of learning, and develops attitudes and skills for life-long learning. In contrast, learning technology emerged somewhat more as a "solution in search of a problem." Proponents of technology were convinced that the capabilities of technology had great potential for education.

This paper takes the position that the PBL and learning technology have the *potential* to enhance to each other's strengths. The question is one of relationship and fit. How can instructors most effectively match the power of emerging technologies with the learning process of PBL?

The paper starts by defining what problem-based learning is in terms of its primary attributes. Next, the paper presents a classification system for thinking about the integration of different technologies into problem-based learning. The system identifies four major ways through which technologies can potentially increase the impact of PBL:

- by enhancing the reality of the problem scenario,
- by providing a more sophisticated modeling of the problem-solution process,
- by providing tools for the solution of significant problems of practice,
- and by providing a vehicle for representing the product of the PBL project.

Finally, the paper gives examples that illustrate how learning technology can enhance PBL through each of these four approaches.

"Seeing and hearing are believing but eating is knowing."
(Brother Blue, 1972)

This quotation conveys the limitations of "telling" and "showing" which represent the primary forms of teaching in schools at all levels. "telling" generally comes in the form of an instructor lecture, with or without discussion. "Showing" involves providing learners with "models" that convey accurate representations of what they are learning. These "models" can be in the form of graphic representations, conceptual frameworks, videotapes of desired performances or the like.

The quotation at the outset of this paper takes this metaphor one step further. The phrase, "eating is knowing" further suggests that true knowledge involves a process of taking in something new, digesting it, and making it part of yourself.

In fact, this process is supported by research on learning (Bransford et al., 1986; Brown & Campione, 1981; Brown et al., 1983; Prawat, 1989). This research finds that the incorporation of new learning first requires a reconsideration or digestion of old mental models. Moreover, these researchers would assert that the process of "eating and digesting" results in greater retention and transfer of knowledge.

The past several decades have witnessed a search for new learning methods that enable the development of deeper and firmer understandings of how to apply knowledge, the retention of new learning, and the ability to access knowledge when needed. Problem-based learning is one such learning method that has emerged as a result of this search. Problem-based learning is a student-centered, constructivist learning method that was initially pioneered in medical education in the United States (e.g., Rush Medical School, Harvard University's School of Medicine), Canada (e.g., McMaster University), and the Netherlands (Maastricht University) during the 1980's (Barrows & Tamblyn, 1980; Bok, 1989; deVolder, & deGrave, 1989; **Engel, 1991)**. In the 1990's the use of problem-based learning expanded into other fields including architecture, nursing, education, law, engineering, and management.

Concurrent with the emergence of PBL has been the rapid development of new technologies, many of which have been adapted for use in teaching and learning. Although to some extent, learning technologies have been "solutions in search of a problem" the potential of these technologies for enriching the learning process has been almost irresistible. The question is how best to use the capabilities of technology in teaching and learning.

The goal of this paper is to examine the relationship between emerging technologies (e.g., software, hardware, multi-media) and PBL. The paper explores the range of possible roles that these technologies can play in the enhancement of PBL. This paper begins with the assumption that in order for technologies to assist in learning, they must be used within a pedagogical framework. PBL represents one such framework. This paper will:

- Discuss what is problem-based learning;

- Present a framework for thinking about the use of learning technologies in problem-based learning;
- Provide examples through the description of several technology-enhanced PBL projects used at the College of Management, Mahidol University (CMMU).

What is Problem-based Learning?

Before discussing the uses of technology, it is necessary to define what we mean by problem-based learning. In our experience training faculty in PBL, we have found that an important first step is to clarify misunderstandings about what PBL. In particular we need to clarify how the goals and processes of PBL differ from the case method (Bridges & Hallinger, 1995; Christensen, 1995).

Defining Characteristics of Problem-based Learning

PBL was first formally introduced by faculty in leading medical schools that were dissatisfied with the quality of the professional preparation they were providing to students (Barrows & Tamblyn, 1980; Bok, 1989; deVolder & deGrave, 1989; Schmidt 1983; Schmidt, Dauphinee, & Patel, 1987). Knowledge application, problem-solving skills and attitudinal dimensions of effective medical practice were all areas that their own assessments identified as persisting weaknesses (Bok, 1989; Schmidt, 1983; Walton, 1989). Notably this self-critique was led by some of the top medical schools in several nations (e.g., Bok, 1989). PBL emerged as a response to these perceived weaknesses in the professional preparation of doctors.

Subsequently, the designers of PBL sought to develop an approach to learning and teaching that would address the following goals:

- Adapting to and participating in change,
- Dealing with complex, swampy problems and making reasoned decisions in unfamiliar situations,
- Reasoning critically and creatively,
- Adopting a more universal or holistic outlook,
- Practicing empathy, appreciating others' points of view,
- Collaborating productively in groups or teams,
- Identifying one’s own strengths and weaknesses and undertaking appropriate remediation. (Engel, 1991, pp. 45-46)

The method that came to be known as problem-based learning emerged gradually over a 10-year period with numerous variants. However, at its heart, PBL has six defining characteristics:

1. The starting point for learning is a problem.
2. The problem is one that students are to apt face in the future workplace.
3. Subject matter is organized around problems rather than the disciplines.
4. Students assume a major responsibility for their own instruction and learning.
5. Most learning occurs within the context of small groups rather than lectures.

6. The solution to the focal problem has an implementation focus that goes beyond problem diagnosis and analysis. (Bridges & Hallinger, 1993, 1995)

As Barrows and Tamblyn (1980) note, in problem-based learning "the learning results from the process of working towards the understanding or resolution of a problem. The problem is encountered first in the learning process, rather than facts, models, conceptual frameworks, or other information. The problem serves as a stimulus and focus for problem-solving and learning."

Thus, the role of the focal problem in PBL is quite different from the typical use of *problems* in cases. In PBL, focal problems are *not* presented to students for the purpose of giving them practice in applying previously learned information; rather they are used as the stimulus for *new* learning. This is an important characteristic that distinguishes problem-based learning from other problem-oriented approaches such as the case method (Bransford et al., 1986; Bridges & Hallinger, 1995; Brown & Campione, 1981; Brown et al., 1983; Christensen, 1987).

Moreover, in PBL learning how to solve problems occurs in the process of learning the subject matter of the discipline rather than as a discrete skill (Prawat, 1989). Development of skills in problem-solving as an individual and as a member of a team are therefore explicit goals of PBL (McGuire, 1980; Norman, 1988; Schmidt & deVolder, 1984)

In contrast to the case method, in problem-based learning the learning objectives and activities are based on the knowledge and skills needed to address problems encountered in the field, rather than on discrete competencies or disciplinary domains (Barrows & Tamblyn, 1980; Boud & Feletti, 1991; Coles, 1985). Knowledge derived from disciplinary domains remains important, but it is organized quite differently. The focus of managerial education, for example, turns from the concerns of the disciplines as conceived by scholars (e.g., psychology, sociology, MIS) to major problems that managers face in the workplace (Bridges & Hallinger, 1995).

Another critical distinction between PBL and the case method lies in the explicit use of *cooperative group learning* in PBL (Bridges & Hallinger, 1995; Dolmans et al., 2002; Schmidt & deVolder, 1984; Norman, 1988; Slavin, 1989; Wilkerson, & Hundert, 1991). The essence of managerial work is being able to accomplish results through people (Bridges, 1977). We contend that in the current environment of decentralized organizations, training experiences should emphasize cooperative problem-solving and teamwork as key areas for development across the professions from medicine to education to management. PBL does this in a more systematic and explicit manner than does the case method.

In PBL the learning experience is structured so as to emphasize *implementation* as well as analysis and reflection (Bridges & Hallinger, 1992, 1995). The most common forms of the case method ask participants to analyze and describe what they would do if they faced a particular problematic situation. In problem-based learning students are asked to develop a plan for responding to the situation and, to the extent possible, execute the plan through different forms of role-play. Thus, learners confront as directly as possible the implementation of their solutions as well as some of the potential consequences of their actions.

Research on problem-based learning, primarily conducted in medical education, has studied a wide range of variables in relation to this learning approach (e.g., see Albanese, 2000; Albanese & Mitchell, 1993; Coles, 1985; Eisenstadt, Barry, & Glanz, 1990; Norman & Schmidt, 1992; Vernon & Blake, 1993; Walton & Matthews, 1989). After almost two decades of research, the differential effects of PBL on learning and problem-solving remain open to question (e.g., Albanese, 2000; Colliver, 2000a, 2000b; Newman, 2001; Norman, 2002; Norman & Schmidt, 2000; Tanenbaum, 1999). In general, it can be said that students studying in a PBL environment do no worse on examinations than counterparts in traditional programs. Where consensus is stronger is on the attitudinal dimensions. It seems fairly clear that PBL produces a more enjoyable and motivational learning environment for students (Norman & Schmidt, 2000).

A Framework for Thinking about the Uses of Technology in PBL

In this section I will present a framework constructed around the components of a PBL project as well as the instructional process of problem-based learning. The framework includes four categories:

- The Problem,
- The Learning Process,
- Tools for Product Development and Problem-solving,
- Product Representation.

[Insert Table One about here]

Using Multi-media Technologies to Convey the Problematic Situation

Role and Nature of Problems in PBL

As noted in the previous section, the problem is the most important component of any PBL project. The problem is the stimulus for the students' learning. PBL problems generally come in two basic varieties: high ground and low-ground (Leithwood & Stager, 1986). High-ground problems are those that appear relatively clear-cut. The outlines of the problem seem straightforward. In many cases, a high-ground problem is not value-laden.

Although PBL has the explicit goal of developing students' abilities to find and solve complex problems, we have two reasons for using high-ground problems in a PBL curriculum. First, PBL programs often give students practice solving high-ground problems first, and then gradually increase the complexity of the problems as students proceed through the program (e.g., Bridges & Hallinger, 1995). Second, high ground problems are also useful when the learning objectives of the PBL project focus on implementation.

Low-ground problems are referred to variously as messy problems, swampy problems, wild problems, or dilemmas. These problems are complex and often require the problem solver to refer to their personal and professional values as well as to data to analyze and solve them. These types of problems are quite common in PBL programs.

Research on the development of expertise across numerous professional domains finds that a key difference between novices and experts lies in their ability to find and identify patterns in a given problematic situation (Bransford et al., 1986; Leithwood & Stager, 1986; Leithwood & Steinbach, 1992; Steinberg & Caruso, 1985; Voss & Post, 1988). PBL seeks to build on this finding by presenting students with multiple problematic situations for analysis and solution. PBL seeks the simultaneous development of students' problem-solving skills and domain-specific knowledge. It is through the application of domain specific knowledge to the solution of problems similar to those that would be encountered in the students' future profession that PBL seeks to accelerate the learning of novices.

How Technology is used in Problem Presentation

With these observations about the nature and role of problems in a PBL project in mind, how can technology be employed at the problem phase? As noted in Table One, there are several ways that designers can use technology in the presentation of the problem. The most common and powerful way is through the actual presentation of the problem through multi-media audio and video.

Video has specific advantages over written or verbally conveyed cases. When the problem scenario is conveyed through written format, many of the contextual cues that are necessary to understanding the problem have already been filtered or processed by the case writer. Although a skillful case writer will embed the important problem-related data in the narrative description and quantitative tables, the reader is asked to "imagine" and "interpret" the context from afar.

Inevitably there will always be a gap between "reality" and what can be presented in a learning situation. The salient issues are:

- How wide is the gap?
- To what extent does the breadth of the gap reduce learning opportunities?
- What can be done to reduce the gap given the available resources?

We would assert that a video representation of a case scenario reduces the gap significantly. While a video-based representation of a problem also contains *processed information*, the viewer is presented with a more immediate and much richer representation of the problematic situation. Given a video scenario, the viewer must find and identify a broader range of cues and use more modalities in processing the available information than in a written case.

By way of example, a written case may refer to the relationship between a manager and a subordinate as "strained", or to a patient as "moderately depressed." The novice student (e.g., a management or psychology student) would need to interpret these descriptions without ever "seeing" what these emotional states look like. Given a video-based scenario, the student would make an interpretation from watching the actual interaction. This introduces two significant differences. First, the student would never have been told that the relationship was "strained." The learner would instead observe the behavior and figure out what to look for. This entails developing the ability to recognize the "patterns" that are a part of professional expertise. Second, having observed the patterns, the learner would then have to draw the conclusion that these behaviors represent "moderately depressed" or "a strained relationship."

Proponents of using technology in PBL take this a significant step further. The video scenario is also designed so as to embed all relevant data about the problem in the "story." Again, the idea is to develop the capacity of the learners to "recognize" the cues and search for the necessary information without being told what is relevant. Information can consist of hard data, relationships, explicit and implicit goals, emotions that are demonstrated, or underlying processes that are at work.

We will give two brief examples of PBL projects that use technology in the presentation of the problem. The first is from a series of video-based PBL projects designed at the *Learning Technology Center* of Vanderbilt University entitled "The Adventures of Jasper Woodbury" (Barron & Bransford, 1993). Here is a synopsis.

> In 1989, John D. Bransford and his colleagues at the Cognition and Technology Group at Vanderbilt University tried an experiment with students. They asked two groups of students to read various passages of technical information. Members of the first group, called the ``facts oriented'' group, were told to remember as much as they could from the passages they had read. Members of the second group, the ``problem oriented'' group, were asked to read the text as though they were planning a trip down the Amazon River.
>
> When tested later on their recall, students in the fact-oriented group gave vague answers, never mentioning any of the specific information they had read. The problem-oriented students, in contrast, recalled a wealth of information, such as the kinds of food and the weight of the water they would carry.
>
> Thus, writes John T. Bruer in his book, Schools for Thought, the seeds were planted for what would eventually become ``The Adventures of Jasper Woodbury.''
> What the researchers had discovered was that people store and retrieve knowledge better when the information is presented in the context of a realistic problem. What if they could ``anchor'' mathematics instruction in that way, and what if the problem contexts were publicly shared so students would have to justify their work?
>
> The Jasper series, a succession of fictional, videodisc adventures about Jasper and his friends, was their answer. In ``Journey to Cedar Creek,'' for example, students must solve a long time-rate-distance problem to determine if Jasper can get his new Chris-Craft cruiser home by sunset. (Viadero, 1996, p. 30)

This series of videodiscs was designed to teach mathematics and science to middle school aged students. Each disc presents an engaging, complex, low-ground problem that students must solve. As suggested above, the data needed to solve the problem are embedded in the story that is unfolded to students. Students must then define the problem and seek the information to solve it.

These video-discs are about as far from the traditional uses of computer-assisted instruction (CAI) in teaching arithmetic calculations as one could imagine. The problems are inherently interesting, engaging and challenging. What are the results of this combination of multi-media technology and PBL?

> Jasper has been constantly and thoroughly researched since its inception in the 1980's. Findings have been incorporated into ongoing development to maximize learning benefits in the classroom. The following are results from a 1990 U. S. study involving sixteen schools in nine states. This diverse population included many students with special needs (e.g., gifted, learning disabled, ESL). Classes using three or four Jasper adventures over a school year were compared with control classes on several measures. Aggregate pretest scores were equivalent for both groups.
>
> Post test data indicate Jasper students performed as well as or better on standardized tests, even though the Jasper classes had spent three or four weeks less on the regular math curriculum. Jasper students also demonstrated superior performance on one-, two, and multi-step word problems. Finally, Jasper students scored much higher on planning and sub-goal comprehension problems than their control counterparts.
>
> In attitude surveys Jasper students showed less anxiety toward mathematics and were more likely to see mathematics as relevant to everyday life. Jasper students were also more likely to appreciate complex challenges. (http://peabody.vanderbilt.edu/ctrs/ltc/Research/jasper_results.html)

Findings from research on the Jasper series of PBL projects confirm the earlier conclusions drawn concerning the effects of PBL on student learning. Student performance on most measures of learning and problem-solving is generally at least as good as from learning from conventional methods. Moreover, students demonstrate attitudes that support more effective lifelong learning. They enjoy the learning process more and learn for meaning rather than reproduction and memorization (Bridges & Hallinger, 1993; Coles, 1985). For example, a teacher involved in the Jasper project reflected on how it changed attitudes towards mathematics.

> *Jasper* helps kids see that you come across a lot of problems in real life that you have to know how to solve that involve math and they involve things that really happen, like running out of gas, or how many miles or many hours does it take you to get from one place to another. And *Jasper* is a much more fun way of learning math than just reading words out of a book. You don't have to be a good reader to do *Jasper* ‹ you just have to pay attention and have some imagination and it built a lot of respect and a lot of self-esteem. Kids like *Jasper* because they got to each contribute and they got to listen to their friends and work with their friends. (http://peabody.vanderbilt.edu/ctrs/ltc/Research/jasper_results.html)

It should be reemphasized, however, that the PBL learning process as exemplified in the Jasper series does not just involve "turning the students loose." This student-centered approach to instruction is systematic. Teachers need to receive training prior to the use of these materials. Subsequently, they must further refine their skills in the classroom in order to obtain such results.

Another example of using technology to present the problem scenario is a PBL project developed at the College of Management, Mahidol University, entitled *Cross-cultural Conflict at Senki Denki (Thailand).* In this project students are introduced to a management problem that has evolved at a Japanese Company operating in Thailand. The scenario involves cross-cultural conflict, a problem with widespread salience in multi-national companies operating in Thailand.

The senior management at Senki Denki Co. (Thailand) has decided to install a new "just-in-time" (JIT) system of production into the Thailand factory. Conflict has developed gradually between the Thai middle manager placed in charge of the new installation and his Japanese Managing Director. The installation of the JIT system is proceeding more slowly than anticipated by the head office, which is creating pressure on the Japanese MD in Thailand.

The complexity of the problem unfolds gradually as the learners come to see the different points of view. These are portrayed through a series of scenes in which the Thai and Japanese managers and staff interact around a variety of implementation issues. The video scenario embeds the data needed for analyzing the sources of cross-cultural conflict in a chronological storyline that evolves over a period of a year.

As suggested earlier the learners must observe and interpret key incidents. These incidents include not only speech, but also body language (e.g., the cultural meaning of conveying certain types of information in front of subordinates), facial expressions (e.g., types of Thai smiles), and tones of voice (e.g., the cultural meaning of behaviors such as raising one's voice). Few of these key "data" would be as effectively conveyed through text (e.g., "He listened with a dry smile."). Narrative descriptions necessarily reduce the richness of the real data and at best represent approximations of the actual behaviors.

The importance of the problem to the process of PBL cannot be overstated. Increased interest in the problem will also increase student motivation for learning. Motivation pays off not only in terms of the level of interest, but also increases retention of information as well as engagement and persistence in the face of challenges (Branford et al., 1989; Eisenstadt, Barry, & Glanz, 1990).

Moreover, the problem scenario also creates “the context” for the students’ interpretation and integration of new knowledge. A concept underlying the rationale for PBL is drawn from the concept of *context dependency* (Bridges & Hallinger, 1995). People are more likely to access stored knowledge needed for solving real problems if they have learned in a context that mirrors the problematic situation (Bransford et al., 1986, 1989; Brown, Collins, Duguid, 1989; Godden & Baddeley, 1975). With this rationale in mind, efforts to convey the problem more realistically, as in a video-based problem scenario, should increase the likelihood of effective pattern recognition and future transfer of learning.

As a final note on the use of technologies to convey the problematic situation, the technologies used for creating multi-media problem scenarios has become less expensive and easier to use in recent years. All of the technology needed for production of multi-media scenarios can be purchased for under $2,500 (USD). These include a digital video camera, CD writer, and computer (PC or Macintosh) with video software and video card.

Using Technologies in the Learning Process

This approach to the incorporation of learning technologies in PBL employs different capacities of IT. Here technologies are used to simulate the “work process” in which the learner would engage while solving problems in their profession. The most common way of accomplishing this is through problem-based simulations. Examples of problem-based simulations have spread through numerous fields of professional education including medicine (Qayumi, & Qayumi, 1999; Rendas, Rosado Pinto, & Gamboa, 1999), management (Glass-Husain, 2001; Hallinger, Crandall, Ng Foo Seong, 2000; Hallinger & Kantamara, 2001; Hallinger & McCary, 1990; Marengo, 1992), health (Westera & Niesink, 2001), and international studies (Brown, & King, 2000; see also www.forio.com).

Simulations tend, by nature, to be well suited for problem-based learning. Whether or not they are problem-based depends upon how the learning process is structured for learning. For example, when we use simulations in a PBL mode, we continue to place students in learning teams of two to four students. We do this even when the computer facilities are sufficient for students to learn individually. This enables us to take advantage of the cooperative learning aspect of PBL, a feature that often is not explicitly incorporated into simulations (Hallinger et al., 2000; Slavin, 1989). Other features that comprise a PBL project (see Bridges & Hallinger, 1995) are similarly organized to support the learning process.

Problem-based simulations present learners with a problematic situation which they must solve using a computer-simulated process. The situation may be represented via video, text, or a combination. Although, the same advantages of video-based scenarios would apply for simulations, most simulations that we have viewed still rely on text.

The learning process of a computer-based simulation uses the computer's ability to model and execute complex relationships and decision rules. The designer of a problem-based, computer simulation can create a scenario, identify theories and best practices salient to the problem, and build those into a highly sophisticated problem-solving process. The computer allows a more sophisticated modeling of "reality" (including random events) than an instructor could typically bring into a classroom simulation using only live or text resources. This is especially the case when you wish to give many students the chance to solve the problem, a limitation of live role-plays.

For example, in the *Making Change Happen!* simulation, learners are given the charge of implementing new information technology into an organization. The problem is conveyed via text on the computer screen (See Hallinger, Crandall, Ng Foo Seong, 2000). A synopsis of the problem follows.

> The new Managing Director (MD) of a company has decided to implement new IT as a driver to increase competitiveness. The company will proceed by pilot testing the use of the new IT at two branches in the Central Region of the organization's operations. Based on results of the trial in these branches, implementation will then roll out into other branches and regions. Despite this step-by-step approach, the MD is under pressure to show results soon. Therefore trial implementation will begin immediately.
>
> You have been selected for special assignment to the team of internal consultants responsible for managing trial implementation of IT 2020 in the Central Region of the organization. Your team is comprised of people from different roles in the Central Region. You will coordinate with Beth, the Management Information System (MIS) Manager in the Head Office, and also with Al, the Regional Director. Two members of the company's Board of Directors -- Carol and Dave--have been assigned by the Chairman of the Board to monitor this project.
>
> Your team will lead implementation of IT 2020 over a three-year period. In each year you will have a budget to spend on specific activities designed to foster use of IT 2020 among staff in these pilot branches. Your success will be assessed annually and at the end of three years to see how widely staff are using IT 2020 and the effects on productivity.

The learners are given sufficient additional information about the people and the situation to proceed with development of a strategy for implementing this change in the company. They implement their strategy through a series of decisions, each of which generates a response from the computer. The team *experiences* the responses of people in the company to their implementation strategy over a three-year period. The computer not only models change in the staff attitudes and behavior, but also changes in the company's productivity that accompany implementation of the new IT.

We would emphasize that in cases where PBL is incorporated into a simulation, there is always a knowledge base of theory and best practices underlying the decision process. In the case of this PBL simulation, the knowledge base derives from theories and research in the fields of organizational change, psychological change, and knowledge dissemination (Hallinger, Crandall, Ng Foo Seong, 2000). However, in PBL the theory is not taught in advance of the learning. Students *construct* their understanding of relevant theory through the process of solving the simulated problem.

Student response to this simulation in our Master Degree program has been almost uniformly positive. Average ratings for the project have consistently exceeded the overall mean rating of other courses in the college each term in which it has been used in our capstone program.

We also give "talk-back" sheets to students at the completion of each project. These seek formative feedback used for improvement of the project. This feedback supplements quantitative and qualitative data collected in the normal course evaluations.

The first question asks: "How did you feel at about the project when you first read what it involved?" A typical set of responses drawn from numerous sections that have used the simulation include: challenging, difficult, nervous, interested, complicated, uncertain, eager to learn, lacking confidence, waste of my time, too much data, frustrated, excited, very confusing, useful, not understand what I can learn from it. These responses reflect the combination of ambiguity, uncertainty and incipient interest that typify student attitudes at the start of almost all good PBL projects.

Next we ask, "Now that you have completed the project what are your feelings about it?" Students respond with the following: challenging exciting, interesting, cool, practical, thinking systematically, fun, so cool, learning like in the real world, interesting, appropriate for students with varying experience, applicable to problems faced in life and at work.

When we ask, "What did you learn from the project?" typical responses include:

- Useful for developing my thinking process,
- New way of thinking and analyzing problems,
- Effectiveness of teamwork,
- Learning to think more systematically,
- Learn how and where to look for information before making decisions,
- Makes me realize that getting people to change is not easy, but if I can succeed there is a big return,
- How to develop a strategy using low cost and high effectiveness,
- I can apply the same strategies in my real job,
- Improve myself in facing the changing world,
- If my company implements something new, I feel excited because I understand how to be one of the innovators to make the change happen.

Other PBL simulations may provide learners with more direct access to the knowledge base underlying the simulation. For example, in *Improving Student Success* (Hallinger & McCary, 1990) students studying to be educational leaders confront the problem of how to improve learning and teaching in a school. Although the scenario presents a high-ground problem of school improvement, development and implementation of the "solution" or "product" are quite complex.

The simulation is built around a knowledge base developed through a systematic review of research on the effects of different educational practices on student learning. The research review resulted in the identification of over 40 research-based practices used in classrooms, homes and schools to improve student achievement. Synopses of these "best practices" are incorporated into a database from which learners can draw in formulating an improvement strategy.

The learning process contrasts with a more typical approach in which students would listen to lectures, read articles and perhaps think about how to apply this knowledge to a case. In the problem-based simulation students actually read the synopses while trying to solve the problem. As they proceed in the simulation, learners see the results of their strategy as it is implemented in the simulated school. Thus, from the beginning, their exposure to this knowledge base entails an active engagement of how the knowledge could be "used as a tool" (Bransford et al., 1986, 1989). This characteristic of PBL enhances both retention and transfer of learning.

This approach to leveraging the capabilities of PBL through the use of learning technologies holds great promise. Although computer simulations lack the live interaction that is a part of real problem contexts, they allow a closer approximation of important aspects than is typically possible. In particular, problem-based simulations provide a useful means of getting students to demonstrate the thinking processes that underlie effective professional practice. Again, we come back to the notion that expertise develops in a process of finding key patterns in problematic situations as well as in the solution of problems.

On the technology side, we would note that a wide range of software is available for building simulations. Popular tools include Macromedia Director and Macromedia Flash, as well as simulation builders (e.g., see www.forio.com).

Using Technology as Tools for Solving Problems in PBL

A third way in which technology can be incorporated into PBL is as a tool for problem-solving. Wholly apart from the use of technologies for problem representative or simulation, information technologies, both hardware and software, have an important role in the solution of a wide range of problems across the professions.

In our Master of Management program, we have incorporated several different software programs into our PBL projects as tools for solving relevant managerial problems. The programs include Microsoft Excel, Macromedia Dreamweaver, Microsoft Project, and Microsoft PowerPoint.

It should be emphasized, however, that the PBL project is not designed to teach the software package. Rather we design the PBL project around a problem and look at different ways in which learners might address the problem. Then we may decide to select a relevant software package. Again, students are learning to use the software in the context of a problem relevant to their current or future professional role.

For example, at the College of Management, we have designed a project entitled *Data to Intelligence* (D2I). It proceeds as follows.

> The *Data to Intelligence* (D2I) Module is about how we make sense, gain knowledge, and understand business situations from raw data - the source of corporate intelligence. It is about how we determine what data resource we need to gather in order to obtain meaningful and actionable information. Like other corporate resources, the collection, maintenance and processing of data is a cost to the organization. The more useful and more widely used the data, the more value it can contribute to the organization. Thus D2I is also about how we communicate this meaningful and actionable information to the organization in a coherent presentation that is fast and easy for the audience to absorb.
>
> During the D2I module you will act as a team of consultants to advise an organization on the status of their business environment with a view to provide them with the intelligence on which they can make effective business decisions. You will analyze and make sense of the organization's real-life data to gain meaningful knowledge that will give the organization a clear understanding of the status of their business. Based on this intelligence, you will recommend appropriate actions to the organization. You will then present your recommendations, which are clearly supported by the knowledge that you have derived, to the organization in a professional consulting presentation and report. (http://www.cmmu.net/cpsite/introD2I.asp)

In this project, students use selected features of Microsoft Excel (i.e., pivot table) to learn how to analyze, interpret and display data. The software is used as a tool for enhancing the decision-making of the learners. Other problems would require other applications of a similar nature.

In this project, the technology is used as a tool for problem-solving. One of the project’s learning objectives is “learning how to use Excel for making sense of corporate data.” Although this objective is important, it is secondary to the broader goal of learning how to turn data into intelligence.

The use of other tools may also fall into this category regardless of whether they are software, hardware, or other type of equipment. The use of new laser technologies to address surgical problems, for example, would place the technology in a comparable role in the PBL process.

The Use of Technologies in the *Product* of the PBL Process

The last of the categories involves the use of technologies for the representation of the product itself. We have found that after the problem, the product is the most important component of the PBL process. Learners are more highly motivated when they see that their solution to the problem will be conveyed in the form of a workplace-type product. Moreover, the fact that they begin to think in terms of the product relatively early in the project again places the knowledge in an "active perspective" (Prawat, 1989). This also means that the learner must measure their solution against more realistic criteria than might otherwise be the case. As Prawat has observed:

> The advantage of such an approach is that students become much more aware of how the knowledge they are acquiring can be put to use. Adopting a problem-solving mentality, even when it is marginally appropriate, reinforces the notion that the knowledge is useful for achieving particular goals. Students are not being asked to store information away; they see how it works in certain situations which increases the accessibility. (Prawat, 1989, p. 18.)

Whereas the prior category cast technology as a tool for *creating the product,* here technology is a key tool in *representing the product*. Although, in a sense, this is a less significant application of technology to PBL, it is worth mentioning.

At the College of Management we have designed a PBL project entitled *retail to e-tail*. The project encompasses the following.

> The program of lectures and problem solving sessions are designed to acquaint students with an overview of marketing principles as they relate to the implementation of an E-Commerce venture.
>
> A large number of SMEs from a variety of industrial sectors are struggling with the challenge of trying to create an online venue for their products. Success in the E-Commerce sector often depends upon the integration of sound management principles with innovative thinking.
>
> The problem presented to the students is representative of the current business climate where small and large companies are struggling with how to utilize the Internet to increase sales, decrease costs and increase profitability. The students take the role of the Marketing Consultants specializing in E-Commerce solutions. They are asked to produce an E-Marketing Strategy including a prototype website for the client.

> Students are encouraged to choose effective options that are available to businesses attempting to create an online avenue for their products. The students will gain experience in critical thinking and effective team collaboration skills. Overall students will have the responsibility of learning E-commerce related content, problem solving skills as well as effective team participation.

Actually, this project uses technologies in three of the four ways discussed in this paper. Students' first exposure to the problem is through a video scenario. We have designed several variations of this project. One is situated in a shoe factory, a second in a jewelry company, and the third in a company promoting Thai boxing. Second, students also use technology as a tool as they learn to use Adobe *Dreamweaver*, a software package used to design websites.

Finally, two of the products are represented via technology. One product is the team's website, which is uploaded and posted on-line. The second is a PowerPoint presentation. Both of these products are actually presented via technology. We could envision similar types of products in other fields such as architecture and medicine where technologies are used to represent the results of a problem solution.

Conclusion

At the outset of the paper, the question was posed concerning the appropriate relationship of technology to PBL. As suggested in the title, there is a range of possibilities.

- As an acquaintance, we would not conceptualize any particular role for technology in PBL, except on an occasional basis. Incorporation of technologies into PBL would tend to be non-systematic and ad hoc.

- As a friend, technology would be available to support PBL where mutual interests converge. The frequency of contact and the degree of interdependency would increase. Use would be more systematic and based on a set of mutually accepted principles.

- As a lover, the futures of both approaches would be intimately intertwined. In this relationship, it would be hard to imagine PBL without technology. Similarly, we would not expect to see technology being used on a regular basis with other teaching and learning approaches.

This paper has presented a theoretical rationale for the incorporation of information technologies into problem-based learning. Earlier I referred to research on the outcomes of PBL that incorporates technologies. While there is less solid empirical evidence than we might like on the effects of this partnership, users of these technologies quickly become aware of their ability to model processes in ways heretofore unavailable.

Although practice currently outpaces research in this domain, I am confident that this is not a fad. At the College of Management, Mahidol University, all of the PBL projects that comprise our capstone course sequence use technologies in at least one of the ways described in this paper (see Hallinger, Blackwood, & Tannaphai, 2002).

We do this for the reasons outlined in this paper:

- We believe that it accelerates our students' skill in finding problems, recognizing patterns in problematic situations, and designing appropriate solutions (Bransford et al., 1986, 1989; Copland, 2000, 2002; Leithwood & Stager, 1986; Leithwood & Steinbach, 1992).

- Given our goal of developing student capacities for learning how to apply and evaluate the use of knowledge, the learning-by-doing emphasis of PBL appears well suited. Both research and our experience suggest that technology has the potential to enhance the process and outcomes of learning in a PBL mode.

- We believe that the ability of our students to bring new ways of thinking as well as new skills to the workplace is largely what will make them more competitive. Thus, we have designed our PBL curriculum to incorporate technologies that will enhance our students' ability to understand problems (e.g., in *D2I* described earlier) as well as to develop innovative solutions.

In conclusion, I would suggest that the appropriate relationship between technology and PBL is that of friends. There remain many effective ways to use PBL without the use of any technology whatsoever. Thus, there are times when each will go its own way quite successfully. On the other hand, there is much to be gained from this partnership. To leave the relationship at the level of acquaintance would be to leave the full potential of PBL untapped.

As an addendum to this discussion, I would note that nowhere in this paper have I referred to the role of PBL in distance learning. Here again, PBL provides a pedagogical theory on which to base distance learning programs. Again technologies have multiple ways to combine with PBL to create effective learning in both synchronous and asynchronous modes of distance learning.

Figure One: Taxonomy of Technology Uses

Problem	Process	Tools	Product
• Technology is used to present the problem • Use video to give information on the problem • Embed info in video and text description • Provide a query-based system of info-giving and retrieval about the problem • Examples: – *Problem of Senki Denki* Project – *Jasper Woodbury* Series	• Technology is used to simulate the process related to the problem • Provides access to a data-base of knowledge used for problem-solving • Technology is used as a "shell" that enables access to the problem as well as other resources • Examples: – *Making Change Happen!* Project – *Strategies for Success* Project – *Improving Student Success* Project – Human organ function – Spread of a disease in a community	• Tech is a tool for generating or analyzing info to make a decision and solving the problem – Statistics program – Excel • Tech is a tool for creating the product – Word processor – Web design program – Database program – CAD • Examples: – *D2I* Project – *Projects and People*	• Tech is used as a means of conveying the product • Examples: – Website – Presentatio n – CAD • Examples: – *Retail to e-tail* Project

References

Albanese, M., & Mitchell, S. (1993). Problem-based learning: A review of literature on its outcomes and implementation issues. *Academic Medicine, 68*(1), 52-80.

Albanese, M. (2000). Problem-based learning: Why curricula are likely to show little effect on knowledge and clinical skills. *Academic Medicine, 34*, 729-734.

Barron, L., & Bransford, J. (1993). The Jasper experiment: Using video to furnish real-world problem-solving contexts. *Arithmetic Teacher, 40*(8), 474-479.

Barrows, H., & Tamblyn, R. (1980). *Problem-based learning: An approach to medical education.* New York: Springer.

Bok, D. (1989). Needed: A new way to train doctors. In H. Schmidt and others (eds.), *New directions in medical education*. New York: Springer Verlag, 17 - 38.

Boud, D. & Feletti, G. (1991). *The challenge of problem-based learning*. New York: St. Martin's Press.

Bransford, J., Franks, J., Vye, N., and Sherwood, R. (1989). New approaches to instruction: Because wisdom can't be told. In S. Vosniadou and A. Ortony (Eds.), *Similarity and analogical reasoning* (470-497). New York: Cambridge University Press.

Bransford, J., Sherwood, R., Vye, N., & Rieser, J. (1986). Teaching thinking and problem-solving. *American Psychologist, 41*(10), 1078-1089.

Bridges, E., with Hallinger, P. (1992). *Problem-based learning for administrators.* Eugene, OR: ERIC Clearinghouse for Educational Management.

Bridges, E. & Hallinger, P. (1993). Problem-based Learning in medical and managerial education. In P. Hallinger, K. Leithwood & J. Murphy (eds.), *Cognitive perspectives on educational leadership*. New York: Teachers College Press.

Bridges, E. & Hallinger, P. (1995). *Implementing problem-based learning in leadership education.* Eugene, OR: ERIC Clearinghouse for Educational Management.

Bridges, E. (1977). The nature of leadership. In L. Cunningham, W. Hack, & R. Nystrand, *Educational administration: The developing decades*. Berkeley, CA: McCutchan, 202-230.

Brown, A., Bransford, J., Ferrara, R., & Campione, J. (1983). Learning, remembering and understanding. In J. Flavell & E. Markman (Eds.), *Carmichael's manual of child psychology, Vol. I.* (77-166). New York: Wiley.

Brown, A., & Campione, J. (1981). Inducing flexible thinking: A problem of access. In M. Friedman, J. Das, & N. O'Connor (Eds.), *Intelligence and learning* (pp. 515-530). New York: Plenum.

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher*, *18*(1), 32-42.

Brown, A. L., & DeLoache, J. S. (1978). Skills, plans and self-regulation. In R. Siegler (Ed.), *Children's thinking: What develops?* (pp. 3-35). Hillsdale, NJ: Lawrence Erlbaum.

Brown, S., & King, F. (2000). Constructivist pedagogy and how we learn: educational psychology meets international studies. *International Studies Perspectives, 1*(3), 245-255.

Bunnag, S. (1997, August 5). Poor academic performance of students blamed on rote system. *Bangkok Post*, p. 2.

Christensen, C. (1987). *Teaching and the case method: Text, cases and readings*. Boston: Harvard Business School.

Coles, C. (1985). Differences between conventional and problem-based curricula in their students' approaches to studying, *Medical Education*, *19*, 308-309.

Colliver, J. (2000a). The effectiveness of problem-based learning curricula: Research and Theory, *Academic Medicine*, *75*, 259-266.

Colliver, J. (2000b). Effectiveness of PBL curricula: Research and Theory, *Medical Education, 34*, 959-960.

Copland, M. (2000). Problem-based learning and prospective principals' problem-framing ability, *Educational Administration Quarterly*, *36*(4), 585-607.

Copland, M. (2003). Problem-based leadership development: Developing the cognitive and skill capacities of school leaders. In P. Hallinger (ed.), *Reshaping the landscape of school leadership development: A global perspective.* Netherlands: Swets & Zeitlinger.

deVolder, M. & deGrave, W. (1989). Approaches to learning in a problem-based medical programme: A developmental study, *Medical Education, 23*, 262-264.

Dolmans, D., Gijelsaers, W., Moust, J., de Grave, W., Wolfhagen, I., van der Vleuten, C. (2002). Trends in research on the tutor in problem-based learning: Conclusions and implications for educational practice and research. *Medical Teacher, 24*(2), 173-180.

Drucker, P. (1995). *Managing in a time of great change.* New York: Talley House, Dutton.

Eisenstadt, R., Barry, W., & Glanz, K. (1990). *Problem-based learning: Cognitive retention and cohort traits of randomly selected participants and decliners*. Paper presented at the Twenty-ninth Annual Conference of the Society of Research in Medical Education.

Engel, C. (1991). Not just a method, but a way of learning. In D. Boud & G. Feletti (Eds.), *The challenge of problem-based learning*, New York: St. Martin's Press, 23-33.

Fullan, M. (1993). *Change forces*. London: Falmer Press.

Fullan, M. (1991). *The new meaning of educational change*. New York: Teachers College Press.

Fullan, M. & Pomfret, A. (l977). Research on curriculum and instruction implementation. *Review of Educational Research*, *47*, 335-397.

Glass-Husain, W. (2001). Three perspectives on business simulation. http://www.forio.com/article_threeperspectives.htm

Godden, D. & Baddeley, A. (1975). Context dependent memory in two natural environments: On land and underwater. *British Journal of Psychology, 66*, 325-332.

Gragg, C. (1941, October 19). Because wisdom can't be told. *Harvard Alumni Bulletin*. Reprinted by Harvard Business School, HBS Case #451-005.

Hallinger, P., Chantarapanya, P., Sriboonma, U. (1995, July). *Implementing problem-based leadership development in Thailand*. Paper presented at the International Conference in Teacher Education, Chulalongkorn University, Bangkok Thailand..

Hallinger, P., Crandall, D., Ng Foo Seong, D. (2000). Systems thinking/Systems changing: A Computer simulation for learning how to maker schools smarter (141-162). In K. Leithwood and K.S. Louis (Eds.) *Intelligent learning systems*. New York: JAI Press.

Hallinger, P., Crandall, D., & Ng Foo Seong, D. (In press). Making change happen: A simulation for learning to lead change. *The Learning Organization.*

Hallinger, P. & Kantamara, P. (2001). Learning to lead global changes across cultures: Designing a computer-based simulation for Thai school leaders. *Journal of Educational Administration*, *39*(3), 197-220.

Hallinger, P. & McCary, M. (1990). Developing the strategic thinking of instructional leaders. *Elementary School Journal, 91*(2), 90-108.

Hmelo, C. (1998). The cognitive consequences of problem-based learning in the early development of medical expertise. *Teaching and Learning Medicine, 10*, 92-100.

Kindley, R. (2002). Scenario-Based E-Learning: A step beyond traditional e-learning. *Learning Circuits*. www.learningcircuits.com/2002/may2002/kindley.html.

Leithwood, K. A., & Stager, M. (1989). Expertise in principals' problem solving *Educational Administration Quarterly 25*(2), 126-161.

Leithwood, K., & Steinbach, R. (1992) *Education & Urban Society, 24*(3), 317-346.

Lyon, P., & Hendry, G. (2002). The use of the course experience questionnaire as monitoring evaluation tool in a problem-based medical programme. *Assessment & Evaluation in Higher Education, 27*(4), 339-352.

Marengo, L. (1992). Coordination and organizational learning in the firm. *Journal of Evolutionary Economics, 2*(4), 313-327.

Margetson, D. (1991). Why is problem-based learning a challenge? In D. Boud & G. Feletti (Eds.), *The challenge of problem-based learning*. New York: St. Martin's Press, 42-50.

McGuire, C. (1980). Assessment of problem-solving skills, *Medical Teacher*, *2*(3) 118-122.

Mumford, M., Zaccaro, S., Connelly, M., & Marks, M. (2000). Leadership skills: Conclusions and future directions. *Leadership Quarterly, 11*(1), 155-170.

Newman, M. (2001). How effective is problem-based learning? *Education for Health, 14(*2), 333-334.

Norman, G. (1988). Problem-solving skills, solving problems and problem-based learning, *Medical Education*, *22*, 279-286.

Norman, G. (2002). Research in medical education: three decades of progress. *British Medical Journal, 324*, 1559-1562.

Norman, G., & Schmidt, H. (2000). Effectiveness of problem-based learning curricula: Theory, practice, and paper darts. *Medical Education, 34*, 721-28.

Norman, G., & Schmidt, H. (1992). The psychological basis of problem-based learning: A review of the evidence. *Academic Medicine, 67*, 557-565.

Prawat, R. (1989). Promoting access to knowledge, strategies, and disposition in students: A research synthesis. *Review of Educational Research, 59*(1), 1-41.

Qayumi, A., & Qayumi, T (1999). Computer-Assisted learning: cyberPatient A step in the future of surgical education. *Journal of Investigative Surgery, 12* (6), p307-317.

Rendas, A., Rosado Pinto, P., & Gamboa, T. (1999). A computer simulation designed for problem-based learning. *Medical Education, 33*, 47-54.

Schmidt, H. (1983). Problem-based learning: Rationale and description, *Medical Education*, *17,* 11-16.

Schmidt, H. & deVolder, M. (1984). *Tutorials in problem-Based learning*. Maastricht, Netherlands: Van Gorcum.

Schmidt, H., Dauphinee, W., & Patel, V. (1987). Comparing the effects of problem-based and conventional curricula in an international sample, *Journal of Medical Education, 62*, 305-315.

Slavin, R. (1989). Cooperative learning and student achievement. In R. Slavin (Ed.), *School and Classroom Organization*, N.J.: Prentice-Hall, 129-156.

Steinberg R. J., & Caruso, O. R. (1985). Practical modes of knowing. In E. Eisner (Ed.), *Learning and teaching the ways of knowing* (pp. 133-158). Chicago: University of Chicago Press.

Tanenbaum, S. (1999). Evidence and expertise: The challenge of the outcomes movement to medical professionalism. *Academic Medicine, 74*, 767-773.

Vernon, D., & Blake, R. (1993). Does problem-based learning work? A meta-analysis of evaluative research. *Academic Medicine, 68*(7), 592-604.

Viadero, D. (1996). Learning with Jasper. *Education Week, 15*(17), 30, 33.

Voss, J. F., & Post, T. A. (1988). On the solving of ill-structured problems. In M.T.H. Chi, R. Ginset, & M. J. Fart (Eds.), *The nature of expertise* (pp. 261-285). Hillsdale, NJ: Lawrence Erlbaurn.

Walker, A., Bridges, E., & Chan, B. (1996). Wisdom gained, wisdom given: Instituting PBL in a Chinese culture. *Journal of Educational Administration, 34*(5), 12-31.

Walton, H. & Matthews, M. (1989). *Essentials of problem-based learning*. Medical Education, 23, 542-558.

Westera, W., & Niesink, R. (2001). Coping with Research Evidence: a multimedia approach for further training of professional workers in the field of drugs and addiction. *Drugs: Education, Prevention & Policy, 8*(3), 281-292.

Wilkerson, L. & Hundert, E. (1991). Becoming a problem-based tutor: Increasing self-awareness through faculty development. In D. Boud & G. Feletti (Eds.), *The challenge of problem-based learning*. New York: St. Martin's Press, 159-172.

Bio Information

Prof. Dr. Philip Hallinger is Executive Director of the College of Management, Mahidol University. His research interests include organizational change, leadership and educational quality. Correspondence about this paper can be directed to him at: Philip.h@cmmu.net