PROBLEM-BASED LEARNING IN ONLINE ENVIRONMENTS

Yun-Jo An
Option Six, Inc.

Charles M. Reigeluth
Indiana University Bloomington

This study examined 3 graduate-level online courses that utilized problem-based learning (PBL), considering each course as a case. Beyond describing how PBL was implemented in each case, this study identified what worked (strengths) and did not work (weaknesses) in the PBL and explored how the PBL could be improved (improvements) by collecting both descriptive and evaluative data. Data were collected from interviews, observations, and document review. Based on cross-case analyses, this study proposed a series of guidelines for designing and implementing PBL in online environments. They provide practical tips for diverse stages of the design and implementation of online PBL.

INTRODUCTION

Problem-based learning (PBL) is a learner-centered instructional approach that aims to help learners acquire problem-solving, reasoning, and metacognitive skills as well as domain-specific knowledge, by using an authentic, complex, and ill-structured problem as the starting point of, and stimulus for, learning in a collaborative learning environment (Barrows, 1986; Savery & Duffy, 1995). The importance of problem solving has been noted by many educators and researchers, and prob PBL has been used in a variety of disciplines and levels. Research indicates that PBL promotes more in-depth understanding of content (Coles, 1985; Newble & Clarke, 1986; Vernon & Blake, 1993) as well as the retention and application of knowledge acquired (Berkson, 1993; Norman & Schmidt, 1992), fosters self-directed learning skills (Barrows & Tamblyn, 1980; Norman & Schmidt, 1992), and provides an enjoyable and stimulating learning environment for both students and teachers (Albanese & Mitchell, 1993).

With the rapid growth of online learning and the need for innovation in instruction, many instructors are trying to use PBL in their

• **Yun-Jo An**, Option Six, Inc., 3350 S. Oaklawn Circle, Bloomington IN 47401. Telephone: (812) 272-2271. E-mail: yunjo@optionsix.com

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online courses. However, we currently do not have sufficient guidance for designing and implementing PBL in online environments. Most PBL models and guidelines available are for PBL in face-to-face environments, and they do not provide appropriate guidelines for online PBL. In addition, current literature on online PBL, which consists of many individual cases that focus on some parts of PBL, such as tools or scaffolds used in problem solving, does not provide the whole picture of the design and implementation of online PBL. Therefore, the purpose of this study is to provide a first step in creating more comprehensive and practical guidelines for designing and implementing PBL in online environments.

PBL AND COLLABORATION

Uribe, Klein, and Sullivan (2003) investigated the effects of computer-mediated collaboration on solving ill-defined problems, and found that learners who worked in computer-mediated collaborative dyads performed significantly better than did ones who worked individually. However, considering that computer-mediated collaboration in their study included only synchronous communication in a computer laboratory, the result may not be applicable to asynchronous online settings. Additional empirical research is required to validate the effects of collaborative learning on problem solving in asynchronous online environments.

In regard to the collaborative group size in an online PBL environment, Uribe and Klein (2003) hypothesized that as the number of members of a group increases, the positive effect of collaboration on problem solving may decline because, in a synchronous computer-mediated communication system, as the number of users increases, there is an increase in confusion from the simultaneous communications that may inhibit problem solving. As they expected, their study results showed that learners who worked in dyads performed significantly better in solving ill-defined problems than those who worked in teams of four. This study is insightful in that it challenges the general practice of grouping learners into teams of at least three. However, we cannot be sure whether the same result will be obtained in different online collaborative environments. For example, collaborative problem solving through an asynchronous communication system may yield different results. Additional research on the appropriate size of an online collaborative group is needed.

STRUCTURE OF THE COLLABORATIVE PROBLEM SOLVING PROCESS

Most researchers who have studied online PBL or developed models for online PBL appear to believe that a fairly strict structure of the problem solving process is critical for successful implementation of online PBL. Orrill (2002) used a framework of four phases that set milestones for learners. Steinkuehler, Derry, Hmelo-Silver, and Delmarcelle (2002) built a strongly structured network environment that guided learners into a fairly strict sequence of a number of activities of the PBL process. In a similar vein, Dennen (2000) highlighted the importance of task structuring in online PBL. In her study, the increased task structuring appeared to improve learner performance in terms of both process and product over the course of the three projects.

Overall, it seems that a fairly strict structure and guidelines are needed in online PBL. The structure could be either for the whole problem-solving process or for tasks involved in the process. However, there are not sufficient empirical data to validate it. As we can see in the case of McConnell (2002), a loose structure might work well if learners are highly motivated and take initiative in their learning. That is, the structure could vary according to specific situations of the learning environments. Therefore, we should conduct more research on the structure of the online PBL process, considering a variety of variables, including learner motivation, prior knowledge

and experience of learners, class size, and so forth.

SCAFFOLDS AND TOOLS FOR SUPPORTING COLLABORATIVE PROBLEM SOLVING

Educators have created tools for supporting collaborative problem solving, such as Project-Based Learning Support System (Laffey, Tupper, Musser, & Wedman, 1998) and WISE (Bell, 1997). However, most tools have been designed for K-12 learners in face-to-face environments. In response to the need for tools to support adult learners engaging in online PBL, Orrill (2002) helped develop the Asynchronous Conferencing Tool (ACT) (Duffy, Dueber, & Hawley, 1998), which included a discussion space with a labeling system, and examined the ways four groups of graduate students in two graduate-level education courses used the tool in their collaborative problem-solving process. As a result, she found that learners tended to use the tool for logistics, posting messages about due dates, deliverables, and organizing reports, rather than using it for problem solving itself. This indicates that we need to find ways to support both the problem-solving process and the logistics involved in the process more effectively. There should be research on this issue.

Cho and Jonassen (2002) examined the effect of online argumentation scaffolds on ill-structured problem solving in an undergraduate-level introductory economics course, by comparing the groups who used only a bulletin board system to collaboratively solve their problems with the groups that used a constraint-based argumentation tool, Belvedere, to structure their arguments and discussions in the problem-solving process. They found that the use of the argumentation scaffold resulted in significantly more problem-solving actions and increased the generation of coherent arguments. This study showed that we can facilitate the problem-solving process by supporting the generation of coherent arguments.

Saye and Brush (2002) identified two types of scaffolds to guide students to solve ill-structured problems: hard scaffolds and soft scaffolds. Hard scaffolds refer to "static supports that can be anticipated and planned in advance based on typical student difficulties with a task" (p. 81). In contrast, soft scaffolds are human beings who can provide dynamic, situational, and timely support based learner responses. Research on scaffolds for online PBL seems to focus on hard scaffolds. Future research should not overlook soft scaffolds.

RESEARCH QUESTIONS

Given the lack of sufficient guidance for online PBL, the purpose of this study is to provide a first step in creating more comprehensive and practical guidelines for designing and implementing PBL in online environments. The research question and subquestions guiding this study are as follows:

- What guidelines are useful for designing and implementing PBL in an online environment?
  - How is PBL implemented in an online environment?
  - What strategies for PBL work (strengths) or do not work well (weaknesses) under what conditions?
  - How can strategies for PBL be improved?

METHODOLOGY

The formative research methodology developed by Reigeluth and Frick (1999) was adopted. Among the six variations the formative research methodology offers, this study used in vivo naturalistic cases for developing a new theory. This study selected three cases, collected and analyzed formative data and descriptive data on the cases, and proposed guidance for designing and implementing PBL in online environments.

Case Selection

Patton (1990) identified a number of types of purposeful sampling, which seek information-rich cases for in-depth study. Among them, this study used criterion sampling, in which all cases that meet some predetermined criteria are selected. The criteria for course selection were as follows:

- The course should be offered online and use computer-mediated communication for discussion and any other activities associated with problem solving.
- The course should use an authentic, complex, and ill-structured problem (or problems) as the stimulus for learning.
- The course should use a learner-centered approach.
- The course should help learners acquire both domain-specific knowledge and domain-independent knowledge, such as problem solving, reasoning, metacognitive, and communication skills.
- The course should require learners to solve a problem collaboratively in small groups.

Three graduate-level online courses that met all selection criteria were selected: Technology: Use and Assessment; Introduction to Reference; and Advanced Problems in Librarianship: Collection Development. They were all at different universities.

Data Collection and Analysis

From each case, two kinds of data were collected: descriptive and evaluative. These data were collected from multiple sources, including interviews, observations, and document review.

The researcher conducted virtual observations of the three online courses throughout the 2005 Fall semester, mostly reading asynchronous discussions. For the third case, the researcher also read and listened to archives of synchronous communications and attended a synchronous class meeting. The researcher interviewed each instructor twice via telephone: once during the course, and once at the end of the course. A semistructured interview protocol was used. Each interview took about 30 to 60 minutes and was recorded for analysis with a digital voice recorder. Student interviews were conducted after the semester (between December 13 and 19) in order to collect data about their experiences with, opinions about, and reflections on online PBL, as well as data about how they would want to improve the problem-solving process. Course documents such as course syllabi, learning resources, student reports, and reflection papers were collected for review. Qualitative data from the cases were analyzed using the constant comparative method (Strauss & Corbin, 1990). After analyzing data from each case, cross-case analyses were conducted.

Methodological Issues

In order to enhance trustworthiness, the first author collected data from multiple sources (triangulation), conducted member checking (Lincoln & Guba, 1985; Stake, 1995), and provided important raw data in this report. She also tried to enhance the transferability of this study, parallel to external validity in quantitative research (Lincoln & Guba, 1985), by using multiple cases (Yin, 2003) and providing thick descriptions of each case.

RESULTS FOR CASE 1: PBL IN TECHNOLOGY: USE AND ASSESSMENT

Case Description

Technology: Use and Assessment was a three-credit-hour graduate course offered completely online by the Department of Industry and Technology at a Midwestern university during the fall semester 2005. There were nine students, all of whom were master's students in technology education. Six of them were technology teachers in K-12. These students

were from six different states. Blackboard 6 was used as the course management software. As the course title indicates, this course examined issues related to technology use and technology assessment. PBL was used for the technology assessment (TA) part.

Implementation

*Problem Presentation***.** In week 9, the instructor presented a problem in a letter, which was assumed to be written by Pete V. Domenici, who was the chair of the U.S. Senate Committee on Energy & Natural Resources, to formalize the award of a contract between that committee and a company for the production of a technology assessment report. In the letter, Senator Domenici first addressed problems of future residential heating resulting from our population growth and our growing dependence on a nonrenewable energy source. Then he requested "a thorough analysis on technologies that are currently available and those that likely could come into use over the next 50 years."

Grading Policy. After the problem presentation, the instructor addressed how the TA activity would be assessed. He intended to assess both process and product of the PBL by using three evaluations: an evaluation of the quality of postings in the group discussion board forums, an evaluation of the final report, and an evaluation of final reflection papers.

Group Formation. The instructor assigned the nine students to three groups based on their previous grades in this class. The top three students formed Team A, the next three students formed Team B, and the last three students formed Team C. A discussion board forum was given to each group.

Cognitive Scaffoldings. The instructor provided cognitive scaffolding throughout the TA activity. He asked thought-provoking questions, raised new issues, and modeled critical thinking in the group discussion board forums.

Are You on Track? The instructor expected the students to determine the appropriate problem-solving process themselves and set their own timelines (November 10, 2005). However, he provided organizational suggestions for those who needed more structure by providing an "Are You on Track?" section every week. He intended to "provide structure where the students feel they need more structure but not to impose the structure on them" (December 8, 2005).

*Comments on TA Reports***.** After the groups submitted their final reports, the instructor created a forum named "Comments on TA Reports," placed the links to the reports in the forum, and encouraged the students to look at other teams' reports and post comments. Although the same problem was given, each group produced a very different TA report. The students were amazed at the differences and could see what they missed and think about how they could have done it better.

Reflection. After the final reports were submitted, the instructor asked the students to write a reflection paper. He suggested that they reflect on "what they have learned about the topic, about technology assessment, about collaborating in an online team, about themselves, and about other areas that arose." In the reflection papers, the students talked about how difficult it was to reach a common understanding of the problem and to find appropriate information from the many resources available. They also often mentioned how frustrating it was to wait for other group members' responses and how helpful it was to have synchronous discussions. Interestingly, they talked about how differently they would approach the problem if they were given the same problem or a similar one again.

Feedback and Grades. The instructor provided very lengthy and detailed feedback to each student on their group report, on their contribution to cognitive dialogue, and on their reflection. He believed that further learning in this class would happen when the students read his feedback, since he addressed what they missed (December 8, 2005).

Strengths

*Assessment for Learning***.** The instructor highly emphasized that the focus of the TA activity be on learning through cognitive dialogue, not on production of the TA report, and he assigned 40% of the grade for the activity to individual contributions to cognitive dialogue. Although there was less cognitive dialogue in all forums than the instructor hoped, the students at least learned the value of cognitive dialogue and collaborative learning. The instructor's feedback on the activity also reflected his learning-centered approach and provided the students with opportunities for further learning.

*Flexible Structure***.** The instructor provided flexible structure through the "Are You on Track?" section only for those who needed it. In the loosely structured PBL environment, the students could learn how to direct their own learning and acquire collaborative problem-solving skills by educating themselves about TA almost from scratch and determining their own problem-solving process and timelines, but they could also get guidance when needed.

Cognitive Scaffolding. The instructor provided cognitive scaffolding throughout the problem-solving process. The instructor's persistent efforts to facilitate cognitive dialogue encouraged several students, who were quiet in the beginning, and enabled them to propose a new idea, provide critical feedback, and raise important issues.

*Synchronous Meetings***.** Although synchronous meetings were not planned in this class, Team A wanted to meet synchronously, and the instructor set up two synchronous meetings with Macromedia Breeze for the team. In their reflection papers all three members of Team A talked about how helpful the synchronous discussions were for their team.

> The Breeze program was instrumental in any success that we did have on this project.... With the program, we were able to instantly provide feedback and make progress.… The Breeze session also allowed us to look at the same information so that everyone was literally on the same page. (Michael, December 5, 2005).

Weaknesses

Insufficient Instruction. Before presenting the problem, the instructor provided an overview of the TA topic and examples of TA reports. Despite the information given from week 7 to week 8, the students did not know where to start and were overwhelmed and intimidated. They often described their feeling of being overwhelmed in their forums.

> I feel that there is just sooooo much information out there. I don't know where to begin or end for that matter, and I'm sure I'm going to miss some important information because the volume of information available is too numerous to detail it all. (Allison, November 17, 2005)

The students did not have sufficient background knowledge and experience to solve the complex and highly ill-structured problem within 6 weeks. Consequently, they did not pay enough attention to important issues, they could not engage in quality discussions, and they could not produce what the instructor expected.

Improvements

*Add Practice***.** After the TA activity was over, the instructor thought it would be helpful if students practiced with one or more TA techniques before they engaged in problem solving, and he decided to add some practice in his future class (December 8, 2005).

*Increase Group Size***.** The instructor realized that a team of three was generally too small for the technology assessment activity. He felt that there might have been more postings and more dialogue if teams had been larger. He therefore decided to "increase the group size from three to four" in order to improve online collaboration in his future class (December 8, 2005).

Have Synchronous Meetings. The instructor believed that it might have been better if they had had a synchronous meeting at the outset to enable students to get familiar with each other. He also thought that synchronous meetings would be useful for decision-making times.

Show Relevance. According to the course improvement survey the instructor conducted right after the course was over, the students believed that the TA activity could be improved if it showed how it would affect them as teachers, how it could be used in their classrooms, and how it would help their students.

RESULTS FOR CASE 2: PBL IN INTRODUCTION TO REFERENCE

Case Description

Introduction to Reference was a three-credit graduate course in the library science and information services program at another Midwestern university. As an introductory course, it aimed to familiarize students with reference resources and to enable them to critically evaluate, select, and effectively use them. It had five students in the 2005 Fall semester. The students were working full-time as K-12 teachers or practicing school library media specialists. They were all from western Missouri. The class communicated asynchronously in the Main Forum in Blackboard. There were six assignments, and problem-based learning was utilized for the fifth assignment, the inventory assignment.

Implementation

Problem Presentation. The problem the students were asked to solve collaboratively in this course was to create a reference inventory for a new library.

Information Environment. Although the problem was presented in the first week, the instructor did not ask the students to solve the problem right away. For the first 12 weeks, she helped them gain requisite knowledge by "exposing the students to the information environment they need to solve the problem" (November 9, 2005). By providing what she called the "information environment" with basic resources and tools needed to solve the problem, the instructor intended to enable the students to focus on more creative parts when solving the problem (December 14, 2005).

Group Formation. All five students were assigned to one group, since the instructor believed that four or five is an appropriate size for the particular problem.

Problem Details. There were two mandatory on-campus sessions, which were called Saturday classes, on October 29 and November 19. At the second on-campus session, the instructor provided details for the three parts of the problem. Part 1 was to select a particular level of a school and make a reference collection for the new school library with a level-3 budget. Part 2 was to compile a selection list for a financially challenged school library with one half the budget of the library in Part 1. Part 3 was to create at least one teaching activity for each type of reference resource. The students were asked to work on Part 1 collaboratively in a group, but to work on Parts 2 and 3 individually. Thus, the focus of this study was on Part 1.

Collaborative Problem Solving. After the on-campus session, the instructor created the "Assignment 5 Forum" in the Main Forum and had the students collaboratively work on the problem in the forum. The student group communicated totally asynchronously. Only 2 weeks were given for solving the problem. No other milestones were given. The instructor monitored the discussion board every day to check that the students were doing what they were supposed to be doing (December 14, 2005), but she was not involved in the problem-solving process at all. The students' problem-solving process did not involve much confusion or struggle, contrary to what was observed in the first case. When learning issues were identified, they found needed information fairly quickly. After making main

decisions, such as how much money should be allotted to each Dewey-sensitive area and whether they would apply for grants, they basically worked on their own parts, passing a document back and forth. Thus, a considerable part of their collaborative problem solving was closer to cooperation than to collaboration. However, according to data from the student interviews and reflection papers, the students were able to learn different approaches to creating a reference inventory by observing others' selections and their justifications.

> It was nice to learn what other people were selecting and be able to see their choices. You know, kind of compare … and, you know, surprises and things like that. Basically the collaboration was the best part of it. (Rebecca, December 14, 2005)

Reflection. Writing a reflection paper was required as the last assignment. There were no specific guidelines for the reflection papers. For the inventory assignment, the students briefly discussed what they learned in terms of content and what was challenging, but they did not address any reflection on their collaborative problem-solving process at all.

Assessment. The grade for the inventory assignment depended on the quality of the final report. The problem-solving process was not considered in the assessment.

Strengths

High Relevance. According to the instructor and student discussions, the problem of creating a reference inventory for a new library was closely related to the current or future career of the students. In fact, one of the students had to do exactly the same thing in the very near future for her job. The problem enabled the students to gain practical experience in solving a highly relevant, real-world problem they were likely to face or were already facing in their careers.

Information Environment. For the first 12 weeks, the instructor prepared the students for the problem by providing an "information environment" where the students actively explored a variety of issues regarding reference and became familiar with basic resources and tools needed for solving the problem. Since the students who were taking this introductory course did not have sufficient background knowledge for solving the problem, the information environment was an efficient and effective way to enable them to gain requisite knowledge and to focus on more creative parts rather than on finding facts to solve the problem.

Weaknesses

The Students Engaged More in Cooperation Than in Collaboration. The instructor did not consider the problem-solving process in her assessment. Since the focus of the PBL was on the report, the students did not pay much attention to collaborative learning. They shared some ideas and resources, asked questions of each other, discussed issues, and made plans and decisions together. However, they seemed to do these things only when they had to. They engaged more in cooperation than in collaboration, by dividing the major task that the problem involved into independent subtasks.

Improvements

Problem Revision. After this course was over, the instructor wanted to revise the problem details by asking for policy and selection statements instead of lesson plans. She realized that the students should pay more attention to the policy part, which was very important in creating a reference inventory (December 14, 2005).

Synchronous Communication. The students did not have specific suggestions for improving the problem-based learning in this course. One student simply mentioned that having a chat room would have been great (December 14, 2005).

RESULTS FOR CASE 3: PBL IN ADVANCED PROBLEMS IN LIBRARIANSHIP: COLLECTION DEVELOPMENT

Case Description

Advanced Problems in Librarianship: Collection Development was a three-credit graduate course offered by the graduate school of library and information science at yet another university in the Midwest. This course examined issues affecting collection development and management for libraries. There were 26 students in this course. According to the instructor, the students were highly motivated, bright, and overachieving, and most of them had a full-time job (December 14, 2005). This course had five assignments, and PBL was used for the fourth assignment, consortium evaluation of virtual information systems. The course management system used in this course was developed and owned by the graduate school of library and information science.

Implementation

Problem Presentation. The problem was to form a consortium of libraries, analyze and evaluate library-related virtual information systems by comparing and contrasting various vendors, make a decision on what to purchase and how to pay for it, and write its report (Instructor, December 14, 2005). Although the problem was presented in the beginning of the course, the students were expected to work on the problem throughout the second half of the semester.

*Synchronous Sessions***.** This course held a synchronous session every Tuesday from 4:30 to 6:30 p.m. Usually, the synchronous session provided a live lecture for the first hour, and the second hour was discussion based. Throughout the semester, the class examined a variety of practical issues and problems regarding collection development through the synchronous sessions.

*Group Formation***.** This course held an on-campus session on Sunday in week 7. The instructor used this on-campus session to form groups. Since she believed that students are much more engaged when they work on what they are interested in (December 14, 2005), she helped the students join groups based on their interests. Five groups were formed, and each group had four to six people. Some of these groups were formed ahead of time and were already working on the problem before the on-campus session.

*Collaborative Problem Solving***.** The instructor provided a private bulletin board to each group. She also made chat rooms available for group meetings and allowed the groups to use any communication media available, depending on their preferences and needs.

Only two groups, the Digital Audiobooks and Primary Source groups, were willing to participate in this research study. The Digital Audiobooks group started working on the problem before the on-campus session. One member contributed to the group a great deal by providing a lot of background information and resources and identifying relevant consortia and experts. Based on her work, the group divided its tasks, set timelines, searched for and shared more information and resources, interviewed experts, and engaged in many discussions for evaluation of products and for decision making. They met in their chat room twice to make group decisions. By dividing tasks in a way that all members of the group worked on all components of the problem together, the Digital Audiobooks group engaged in intensive collaboration.

> There were sort of two levels of tasks. The first level was developing library profiles. So which library we're going to represent and what would the library look like.… The second level of the task had to do with the vendors. And so we decided that we each take a vendor and the other person would do expert commentary. (Madison, December 19, 2005)

The Primary Source group members initially attempted to individually work on their own part and assemble parts later on by dividing the task into independent subtasks. However, they soon realized that it required more than that, and they made adjustments (Jennifer, December 18, 2005). They first shared some background resources and their individual library descriptions, and next they made suggestions for potential products and talked about timelines. Then they engaged in evaluation of selected products while contacting vendors, and sometimes had chat meetings after the synchronous session to make group decisions.

No Structure. The instructor did not provide any structure in the problem-solving process. She wanted to make the problem-solving situation more authentic by having the students deal with the problem without her involvement.

> They're not going to have somebody hovering over them when they have to form a consortium in the real world. I don't want to do that. I don't hover. I think that that gives them a better sense of trying to deal with the project because libraries are so cooperative that everyone of them is going to have to work in a consortium to do something at sometime in their lives as a librarian. (December 14, 2005)

Presentations. On December 6, when the final report was due, the five groups made presentations in the synchronous session. During presentations, the students looked at the Web site of the group presenting, listened to the presentation, and sometimes asked questions to the group. After the presentation of each group, the instructor and students made comments.

Process and Peer Evaluation. After finishing their problem solving and presentation, the students were required to write a confidential memo to their library director, who was the instructor. The students were asked to include their evaluation of their collaborative problem solving process and peers with a letter grade for each of their group members in the memo.

Instructor Assessment and Feedback. By having the students evaluate their collaborative problem-solving process themselves, the instructor focused on the quality of the final reports in her assessment. Overall, the instructor was very impressed and pleased with the students' performance in this class. She posted her feedback on the final reports to the private group discussion boards. In her feedback, she discussed what they did well and how, pointed out what they did not consider, addressed an alternative solution, and explained relevant issues.

Strengths

Provided More Learning Opportunities Through Synchronous Sessions. By providing the synchronous sessions, the instructor helped the students think about many issues that were not directly related to their problem solving as well as relevant issues. The students reported that they could learn more than what the problem required them to learn through the sessions.

Enabled Students to Communicate Both Asynchronously and Synchronously. The two groups participating in this study mainly worked in their private bulletin board, but they had chat meetings when they needed to make group decisions. The students perceived that synchronous communication was more effective and efficient than asynchronous communication for decision making.

> We used it [chat room] when we needed to make a group decision, like when we had to decide which vendor we're going to select. (Madison, December 19, 2005)

Considered Both Process and Product of PBL in Assessment. The instructor helped the students pay attention to their collaborative problem-solving process as well as their report by having them write a confidential memo.

Weaknesses

*Insufficient Communication Between Instructor and Students***.** The student interviews revealed that some students had problems with communicating with the instructor about the consortium project. The Audiobooks group did not have any communication with the instructor because their group somehow formed a kind of group norm that they should not ask the instructor for help. It was also found that some students were uncomfortable with asking questions at the synchronous sessions where the instructor encouraged them to ask questions.

Improvements

Tailored Structure. It appeared that some students needed more structure from the instructor, while others were very comfortable with solving the problem on their own**.** Madison in the Digital Audiobooks group mentioned that it might be helpful if the instructor met with each group once or more through conference call to check their progress, provide feedback, and answer questions (December 19, 2005). On the other hand, Jennifer in the Primary Source group believed that there was nothing the instructor could do to better facilitate their problem-solving (December 18, 2005).

GUIDELINES FOR ONLINE PBL

Based on this research, the following are some guidelines that might be useful for designing and implementing PBL in online environments (Figure 1). The guidelines are based on cross-case analyses.

Consider using PBL for part of a course.

One does not have to try to use PBL for the entire course. As a matter of fact, it is difficult and almost impossible to create or find problems that cover all important learning content. Interestingly, none of the three cases used PBL for the entire course. They all used PBL as one of several assignments. Considering the time-consuming nature of PBL and the limited time period of a course, it would be wise to use PBL for a part of a course if other parts of the course can be effectively taught in other ways. Also, it might be necessary to use PBL with other instructional methods when a problem does not cover many important learning issues or when students do not have sufficient requisite knowledge.

Select or create a problem that is relevant to students' current or future careers.

PBL depends on students' self-directed learning, so it is very important to create a problem that is relevant to students in order to get them engaged in learning and problem solving. In the first case, the residential heating technology assessment was an important real-world problem, but it seemed that the problem was not very relevant to the students' careers. On the other hand, the problems in the second and last cases were very relevant to the students' current or future careers, and it made them active in their learning and problem solving. Particularly in the last case, the problem left room for the students to choose the problem context based on their interests, and the students were very active and even over-achieving. When possible, it might be useful to involve students in creating a problem or to allow them to select or define problem specifics based on their interests.

Consider the number of solutions, the problem context and structure, and the available time when creating a problem.

Problems for PBL are typically complex, authentic, and ill-structured. However, they can also vary in many ways, as the problems in the three cases evidenced. Some may ask for one best solution, but others may accept several alternatives. Some may provide a specific context for problem solving, but others may

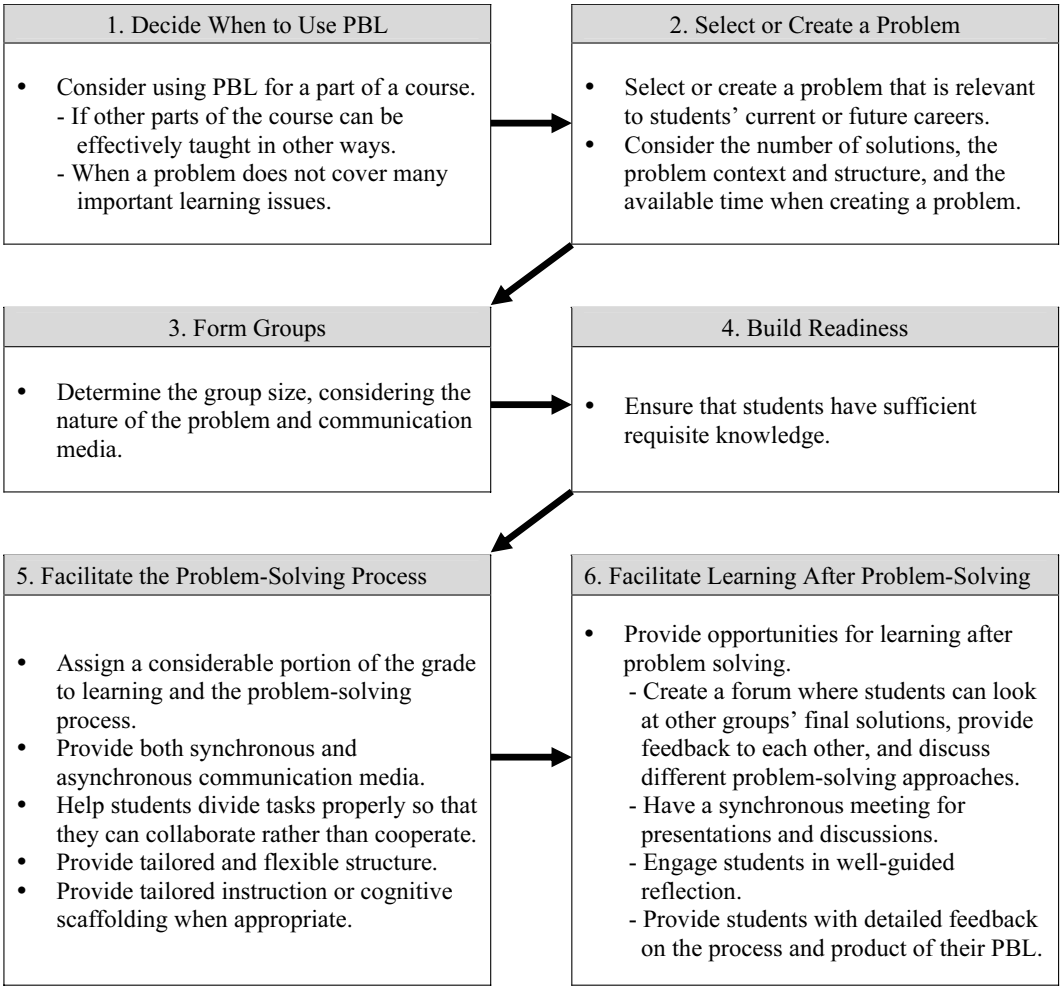

Figure 1
Guidelines for Online PBL

allow students to select the problem context based on their interests. Some may provide some structure by specifying information needs or format of the final product, but others may allow for more flexibility in defining, solving, and presenting the problem. Some may need a whole semester to be solved, but others may be solved in a few weeks. Therefore, when creating a problem, it is worthwhile to consider the number of solutions, problem context, structure, and time to provide a better PBL environment.

Determine the group size, considering the nature of the problem and communication media.

What would be the optimum size of collaborative problem solving groups in online environments? According to the instructors in the three cases, four might be the optimum size for an online collaborative group in general when students mainly communicate asynchronously. When communicating asynchronously, students are often frustrated by no or late

responses from their group members. Therefore, when mainly depending on asynchronous communication, a group needs to have enough people to keep the momentum in their dialogue. However if the group is too large, it would be harder for students to reach a common understanding of a problem, or there might be some students who disappear or lurk.

Furthermore, the size can vary depending on the problem, according to the data from instructor and student interviews. The instructors and several students believed that only a few people could be enough for some problems, but four or five people could be needed for other kinds of problems. Thus, the communication media and the nature of the problem appear to be two important factors to consider when deciding the size of a collaborative group.

Ensure that students have sufficient requisite knowledge.

The results of this study suggest that PBL can be more successful when students have sufficient requisite knowledge. In the first case, the students did not have sufficient requisite knowledge, were overwhelmed by the information made available, did not pay enough attention to important issues, and could not produce quality technology assessment reports. On the other hand, the students in the second and third cases acquired background knowledge through the information environment and synchronous sessions, and they were able to solve their problem successfully without much confusion and struggle. Thus, it is important to figure out whether students have requisite knowledge or not before providing a problem. If students lack requisite knowledge, it might be wise to expose them to basic information and resources so that they can gain sufficient requisite knowledge and focus more on creative or higher-level aspects of problem solving.

Assign a considerable portion of the grade to learning and the problem-solving process.

Assessment drives and shapes student learning, since students focus on what is assessed. If the instructor assesses only final reports, for example, the students are likely to focus on their report, paying little attention to their discussions and collaborative learning, as seen in the second case. On the other hand, if the instructor assesses the quality of discussions as well as the solutions, as the instructor in the first case did, students pay more attention to their problem-solving process. Therefore, it is important to involve both product and process aspects of PBL in assessment.

Provide both synchronous and asynchronous communication media.

Solving a complex and ill-structured problem in a group involves a lot of decision making and requires great interdependence with others. The data from the first and third cases suggest that synchronous communication can be more effective and efficient than asynchronous communication for decision making. On the other hand, asynchronous discussions give students more time to think about the content and enable them to post thoughtful messages. In addition, asynchronous communication allows students to work at their convenient times. Therefore, it is important to make both synchronous and asynchronous communication media available and to enable students to choose appropriate forms of communication depending on their needs.

Help students divide tasks properly so that they can collaborate rather than cooperate.

In PBL, instructors hope that students will learn from group collaboration by testing their own ideas and perceptions against alternative views of others and expanding their understanding and perspectives. The results of this study, however, indicate that students tend to cooperate rather than collaborate by dividing tasks into independent subtasks as much as possible. PBL is meaningful only when students benefit from collaborative learning. In

order to maximize learning from collaboration, instructors should ensure that students divide tasks properly so that they can collaborate rather than cooperate.

Provide tailored and flexible structure.

Previous research suggests that a fairly strict structure for the problem-solving process is helpful for successful implementation of online PBL. However, the results of this study suggest that individual students have different needs for structure and that a rigid structure for the problem-solving process is unnecessary, especially for highly motivated or advanced students.

If instructors define and structure the problem-solving process and have students go through the safe steps, they will probably solve the problem more efficiently without much trial and error. However, it would be hard for them to gain valuable problem-solving strategies that can be learned when they make an action plan based on their knowledge and experience, revise their plan, and manage unexpected problems. Therefore, as the instructors in the three cases contended, it is important to have students determine an appropriate problem-solving process on their own. However, as seen in the first and last cases, some students need more structure from the instructor, while others are comfortable with solving a problem on their own without much structure from the instructor. Therefore, for students who need more structure or guidance, it would be desirable to provide tailored and flexible structure when needed.

Provide tailored instruction or cognitive scaffolding when appropriate.

The results of this study suggest that groups can have different learning needs based on their interests and problem-solving plans. The three groups in the first case had very different learning needs, even though they were working on the same problem. Therefore, an instructor needs to carefully monitor each group and consider providing tailored instruction when appropriate. However, as long as students are not missing critical learning issues, it might be better to facilitate their learning and problem solving by providing cognitive scaffolding, rather than by providing direct instruction. Asking thought-provoking questions, raising issues, and modeling critical thinking can help students be critical, broaden their perspective, and engage in meaningful discussions.

Provide opportunities for learning after problem solving.

Although learning during problem solving is critical, learning after problem solving is also highly important. The findings of this study suggest several ways for facilitating learning after problem solving. First, the instructor can create a forum or have a synchronous meeting, during which students can look at other groups' final solutions, get new insights from comparing and contrasting different solutions, and discuss different problem-solving approaches. Second, the instructor can engage students in reflection. Well-guided reflection can help students make their tacit knowledge gained through PBL more explicit, so it can be easily used in future problem solving. Finally, the instructor can help students learn a great deal after problem solving by providing detailed feedback on the process and product of their PBL.

LIMITATIONS AND FUTURE RESEARCH

The guidelines proposed in this study are based on findings from only three graduate-level courses in the technology and library science fields. Therefore, they might not be appropriate for undergraduate-level courses or for other disciplines. In addition, PBL was used for only a part of a course in all three cases. There might be limitations in applying

the guidelines to PBL that is used for an entire course or for a whole program.

Further studies might explore diverse online PBL courses in different subject areas or disciplines, as well as at different levels of learning, in order to revise and refine the guidelines proposed in this study. Second, it might be interesting to explore online PBL courses where synchronous discussions are more dominant. Finally, future research could explore new technologies for online PBL. In the future, when more advanced technologies are available, we might need to develop different kinds of guidelines for online PBL.

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