Problem-Based Learning

One must reconsider what students really need to learn and the environment in which they learn. Much of the enthusiasm for the problem-based approach to learning comes from instructors who feel revitalized by the creative energy it releases.

Hal White, *"'Creating Problems' for PBL"*

Every quarter faculty are faced with determining how to present course material so that students not only gain knowledge of the discipline, but also become self-directed learners who develop problem-solving skills they can apply in future courses and in their careers. Confronted with these challenges, faculty at Stanford and elsewhere have begun to use *problem-based learning* techniques in their courses. In problem-based learning (PBL) courses, students work with classmates to solve complex and authentic problems that help develop content knowledge as well as problem-solving, reasoning, communication, and self-assessment skills. These problems also help to maintain student interest in course material because students realize that they are learning the skills needed to be successful in the field. Almost any course can incorporate PBL, and most faculty and students consider the benefits to be substantial. This issue of *Speaking of Teaching* identifies the central features of PBL, provides some guidelines for planning a PBL course, and discusses the impact of PBL on student learning and motivation.

Features of Problem-Based Learning

While the content and structure of PBL courses may differ, the general goals and learning objectives tend to be similar. PBL begins with the assumption that learning is an active, integrated, and constructive process influenced by social and contextual factors (Barrows, 1996; Gijselaers, 1996). In their review of the literature, Wilkerson and Gijselaers (1996) claim that PBL is characterized by a student-centered approach, teachers as "facilitators rather than disseminators," and open-ended problems (in PBL, these are called "ill-structured") that "serve as the initial stimulus and framework for learn-

ing" (pp. 101-102). Instructors also hope to develop students' intrinsic interest in the subject matter, emphasize learning as opposed to recall, promote groupwork, and help students become self-directed learners.

Learning is "student-centered" because the students are given the freedom to study those topics that interest them the most and to determine how they want to study them. Students should identify their learning needs, help plan classes, lead class discussions, and assess their own work and their classmates' work (Gallagher, 1997; Reynolds, 1997). "[S]tudents develop a deeper awareness and ownership of important concepts in the course by working on activities, a basic tenet of the constructive approach to learning" (Seltzer, et al., 1996, p. 86).

In addition to emphasizing learning by "doing," PBL requires students to be metacognitively aware (Gijselaers, 1996). That is, students must learn to be conscious of what information they already know about the problem, what information they need to know to solve the problem, and the strategies to use to solve the problem. Being able to articulate such thoughts helps students become more effective problem-solvers and self-directed learners. Initially, however, many students are not capable of this sort of thinking on their own. For this reason, the instructor must become a tutor or "cognitive coach" who models

inquiry strategies, guides exploration, and helps students clarify and pursue their research questions (Arámbula-Greenfield, 1996). The instructor plays a critical role in helping students become self-directed learners and must create a classroom environment in which students "receive systematic instruction in conceptual, strategic, and reflective reasoning in the context of a discipline that will ultimately make them more successful in later investigations" (Gallagher, 1997, p. 337). Gallagher (1997) also suggests that teachers "give voice to metacognitive questions" and "insert them into the classroom dialog so that students learn to attend to them, appreciate their utility, and then adopt their use as they become increasingly independent and self-directed" (p. 340).

Groupwork is also an essential aspect of PBL for several reasons. First, groupwork helps develop learning communities in which students feel comfortable developing new ideas and raising questions about the material (Allen, Duch, & Groh, 1996). In addition, groupwork enhances communication skills and students' ability to manage group dynamics. Finally, groupwork is interesting and motivating for students because they become actively involved in the work and are held accountable for their actions by group members (Cohen, 1994). For these reasons, groupwork can enhance student achievement. However, groups do not always work effectively without guidance. Usually the instructor facilitates and monitors group interactions because many students have not been taught how to work effectively in groups (Bridges & Hallinger, 1996; Wilkerson, 1996). Well-designed, open-ended problems that require the input and skills of all group members also are essential to positive groupwork experiences (Cohen, 1994).

As noted, in PBL literature the term "ill-structured" is used to describe open-ended problems that have multiple solutions and require students "to look at many methods before deciding on a particular solution" (Shelton & Smith, 1998, p. 21). Educationally sound, ill-structured problems "help students learn a set of important concepts, ideas, and techniques" (Gallagher, 1997, p. 338) because they provoke group discussion and give students experience solving problems encountered by experts in the field. Students recognize these problems as professionally relevant. Therefore, students are more likely to be motivated to work on them (as opposed to discrete problem sets or textbook exercises), not only because they realize that the knowledge they gain by thinking about these problems will be useful in the future, but also because students are typically given significant opportunities for creativity and flexibility in solving PBL problems.

Class Structure and Format

Medical schools have relied on PBL since the early 1980s to teach students clinical reasoning. However, undergraduate instructors have begun to use this method only recently, and it is possible that most students have not experienced PBL before. Thus, it is imperative that instructors establish classroom norms that make students feel comfortable in this new learning environment. For instance, mistakes should be viewed as learning opportunities rather than as indicators of lack of ability (Bridges & Hallinger, 1996). In addition, instructors need to find the appropriate balance between allowing students to discuss issues on their own and intervening in group interactions (Gijselaers, 1996). Instructors should also encourage students to develop classroom norms and ground rules for group work, including establishing attendance policies, the schedule of due dates, and the consequences for rule violation.

The day-to-day structure of a PBL course is quite different from the structure of traditional lecture courses. Rangachari (1996) suggests that the first few class meetings in a PBL course include brainstorming sessions in which issues central to the course are identified. Alternatively, the instructor can create an extensive list of topics and ask students to focus on those topics that seem most interesting. Based on student input about course topics, the instructor develops ill-structured problems. Students then work on the problems in groups of three to eight students, depending on the number of students in the course and the number of available instructors or tutors.

Regardless of how topics were selected, the instructor presents the problems to student groups before providing any formal instruction on the topic. (Allen, Duch and Groh [1996], however, suggest that problems be introduced with "minilectures" that provide some context for the problem and identify areas of potential difficulty.) During class time and outside of class students work with their groups to solve problems. Throughout each class the instructor must ensure that all students are involved in the problem-solving process and must familiarize students with the resources needed (e.g., library references, databases) to solve the problems, as well as identify common difficulties or misconceptions (Arámbula-Greenfield, 1996; Seltzer, et al., 1996). With multiple groups exploring different problems or even examining similar problems, the task of coaching groups may be too much for one instructor. Thus, the instructor may want to consider using teaching assistants or tutors who are familiar with PBL methods and techniques to assist groups. Finally, PBL emphasizes depth rather than

breadth of content coverage, with students having from two to six weeks to work on one problem depending on its complexity. Upon completing the research or inquiry phase of problem solving, groups may be required to write a report and present it to the rest of the class.

Developing Ill-Structured Problems

Ill-structured problems:
- require more information for understanding the problem than is initially available.
- contain multiple solution paths.
- change as new information is obtained.
- prevent students from knowing that they have made the "right" decision.
- generate interest and controversy and cause the learner to ask questions.
- are open-ended and complex enough to require collaboration and thinking beyond recall.
- contain content that is authentic to the discipline.
    (Adapted from Allen, Duch & Groh, 1996;
        Gallagher, 1997.)

Students learn best by constructing solutions to open-ended, complex, and problematic activities with class-mates, rather than listening passively to lectures. These types of activities promote discussion among group members and keep students motivated to learn more about the subject. Creating ill-structured problems takes time and creativity but can be extremely rewarding when students achieve their learning goals. Professor Michael Copland, who teaches courses in the Prospec-tive Principals Program in the School of Education at Stanford, believes:

> The key thing in making [PBL] successful is the amount of time and energy that goes into the cre-ation of the project. Finding a problem that really means something to the participants is absolutely critical. [O]nce you find a very salient problem, then structure the learning objectives around that problem and find resources that inform students' thinking about the problem. . . chances are it's going to have some success.

Such problems exist in any discipline. One approach to developing problems is to work backwards from exam questions (Rhem, 1998). For instance, word problems and essays can be expanded into larger cases that require more integration of information. Another approach is to identify current debates in the field of study and have

students explore the major issues. White (1995) argues that even having students read, summarize, and critique journal articles can be a valuable experience. In order to capture students' interest, the instructor may use presen-tation formats such as op-eds from fictitious newspapers, data from experimental studies and case reports (Rangachari, 1996).

Professor Copland uses role-playing as a powerful way to teach students about being a school principal. Students individually spend the afternoon in his office and act out the role of principal. They are presented with

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How to Get Organized for a PBL Course

- Clearly define your purpose for doing PBL, the procedures you will use, and your ex-pectations -- do this BEFORE your first PBL session.

- Assign students to groups by an arbitrary method (such as alphabetically) and distrib-ute the list of assignments to students the class period before the first PBL session. The list should show all groups, numbered, and all members of each group.

- Request a room conducive to group work. For 80 students, a room with tables is best, followed by a room with moveable chairs.

- On the day of your first PBL session, prior to students' arrival, assign seating by pasting group numbers on all seats, if seats are not already numbered.

- Set up your room so that you are accessible to all groups. In a large lecture hall with fixed seating, this may mean leaving empty rows between group rows.

- Bring extra group lists, masking tape, sta-pler, extra textbook, reference materials, and copies of problems for each group and for each group member.

- Anticipate problems and be ready to handle them swiftly.

(Adapted from Dion, 1996)

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live interruptions, such as an angry parent who confronts them in the office, community members who are concerned about students' test scores, and a phone call from a father whose son is being harassed on the school bus. For many students, this role-playing opportunity enables them to understand their chosen career path more deeply because it is the first time they are exposed to the daily demands of being a principal. Most students consider it to be an extremely valuable learning experience.

After problems have been created and even implemented in the curriculum, they should be revised and improved, as needed. Professor Renate Fruchter, the director of the Project-Based Learning Laboratory of the Department of Civil Engineering at Stanford and instructor of the PBL-structured Computer-Integrated Architecture, Engineering and Construction course, identifies four steps or phases involved in formalizing one's problem-development efforts. The first step is "exploration/experimentation" in which the problem is tested with students for the first time. During the next phase, "sustainability," the problem is administered several more times and revised and adapted each time based on student feedback. Professor Copland strongly advocates obtaining student feedback as well, and suggests asking students questions such as "How did this activity work for you?" and "If you could change something about this project, what would you change?" The third step, "institutionalization," involves determining the extent to which the problem is valuable for industry or the domain area. The last step is "reinvention," refreshing the problem so that it reflects the most current and relevant topics of the domain.

Assessment in Problem-Based Learning

Assessment needs to fit the philosophy of active learning rather than passive reproductive learning. . . It may be preferable, and more rigorous, for assessments to follow the PBL philosophy and to require the individual to analyze a problem, search for and then apply relevant information. (Reynolds, 1997, p. 272)

Unfortunately, assessment of PBL is poorly addressed in the research literature. Most studies compare students who have undergone PBL curricula with those who have not by using traditional measures, which tend to be almost exclusively content-oriented. Results of these studies vary, but most indications are that PBL "does no harm" in terms of traditional, content-oriented outcomes (Albanese & Mitchell, 1993; Vernon & Blake, 1993). Yet, if the primary goal of PBL is to have students cultivate the habits of mind evidenced by professionals in

a field or discipline, faculty need to consider process-oriented objectives, and the means by which to assess them.

Process-oriented objectives can be difficult to articulate, although they constitute the "hidden curriculum" of most courses. We want students to understand concepts, formulas, and skills which constitute the knowledge base of a discipline or profession. But we also want them to recognize the kinds of problems embraced by specific disciplines and professions, and the means by which practitioners go about solving them. Process-oriented objectives are those that relate to how practitioners of a discipline or profession think about

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Structuring a Large PBL Course

- Introduce a problem at the beginning of the class, or during the previous class, with a very brief "mini-lecture."

- If the problem is printed (rather than viewed), provide copies for each group and for each person in each group.

- Furnish printed questions related to the problem (with space provided for answers). Copies should be furnished to each group member and a copy to each group. The group's copy, signed by all participating members, should be turned in as the group product at the end of the period. If questions are not appropriate for the problem, then explain what product is expected as a result of the group work for that day.

- If a printed problem is written on more than one page, and solutions to the problem unravel with each new page, then give out the pages one at a time, requiring that answers to one page be turned in before the next is dispensed. Suspense is a great motivator.

- Assess progress at regular intervals. If necessary, interrupt group work to correct misconceptions, or to bring groups up to par with one another.

- Allow time for class discussion of the problem at the end of the PBL session, or at the beginning of the next class period.

(Adapted from Dion, 1996)

and solve problems within a certain field (Toulmin, 1972). Because content-oriented objectives are usually emphasized, those seeking to implement PBL may struggle, initially, with defining, highlighting to students, and then assessing process-oriented objectives. In fact, those who have researched the process-oriented outcomes of PBL have found dramatic results (Hmelo, et al., 1997).

PBL assessments should be authentic, which is to say that they should be structured so that students can display their understanding of problems and their solutions in contextually-meaningful ways (Gallagher, 1997). Clearly, multiple-choice assessments and even short-answer or essay questions that require rote repetition of facts will be of little value in assessing the extent to which students have internalized holistic approaches to complex problems.

A critical part of assessment in PBL is the feedback students receive from their peers. Allen, Duch, and Groh (1996) asked students to rate their group members using a numerical scale based on "attendance, degree of preparation for class, listening and communication skills, ability to bring new and relevant information to the group, and ability to support and improve the functioning of the group as a whole" (p. 49). This peer rating constituted up to ten percent of students' final grades. Peer ratings, however, are not sufficient feedback and neither are single letter grades. The instructor should also provide detailed comments about each student's strengths and weaknesses. Having students evaluate their own performance can be a valuable task as well (Bridges, 1996).

Impact on Student Learning and Motivation

Overall, PBL is an effective method for improving students' problem-solving skills. Students will make strong connections between concepts when they learn facts and skills by actively working with information rather than by passively receiving information (Gallagher, 1997; Resnick & Klopfer, 1989). Although active learning requires additional work on the part of students and faculty, Kingsland (1996) observed that students find PBL courses satisfying. Professor Fruchter has found that students contact her once they are working in the field to tell her how valuable their learning experience has been. She remarks,

> I can tell you tons of stories, which I have been kind of informally collecting over the years. Many

times [students]. . . treat school. . . like. . .[it] is just a simulation. Then they go out and they are in situations which are almost identical to the ones they have experienced in the lab. The learning experience was so valuable because it prepared them to handle, anticipate. . .and prevent some of the miscommunications and difficult situations emerging on every project.

PBL promotes students' confidence in their problem-solving skills and strives to make them self-directed learners.   These skills can put PBL students at an advantage in future courses and in their careers. While such confidence does not come immediately, it can be fostered by good instruction. Teachers who provide a good learning community in the classroom, with positive teacher-student and student-student relationships, give students a sense of ownership over their learning, develop relevant and meaningful problems and learning methods, and empower students with valuable skills that will enhance students' motivation to learn and ability to achieve (MacKinnon,1999).

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WWW Resources

The Buck Institute <http://www.bie.org/pbl/trai.html>
Center for Educational Technologies (NASA's Classroom of the Future) <http://www.cet.edu/profdev/main.html>
Illinois Math and Science Academy <http://www.imsa.edu/team/cpbl/cpbl.html>
Education by Design <http://www.edbydesign.org/assoc/courses.html>
Samford University <http://www.samford.edu/pbl/pbl_main.html>
The University of Delaware <http://www.udel.edu/pbl/>
University of Maastricht <http://www.unimaas.nl/pbl/>

List server: Send the command SUBSCRIBE PBLIST
Firstname Lastname in the body of an e-mail message to listproc@sparky.uthscsa.edu

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