Chapter 8

Problem-Based Approach to Instruction

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Editors' Foreword

Preconditions

Content

- Complex problems that do not have a single correct answer

Learners

- All kinds of learners
- Learners must have some prior knowledge gained from real-world experience.

Learning environments

- A room with large tables, multiple computers, and access to resources
- Instructor and organization must be committed to PBI—the entire approach

Instructional development constraints

- Sufficient time and money to develop for find the problems and learning resources

Values

about ends (learning goals)

- The development of problem solving and decision-making skills within a content domain
- The enhancement of learners' reasoning abilities and self direction
- The enhancement of transfer to real-world tasks

about priorities (criteria for successful instruction)

- Effectiveness is valued over efficiency
- Intrinsic motivation is valued over extrinsic motivation

about means (instructional methods)

- The importance of self-direction
- The use of complex, authentic problems with no single right answer
- The teacher as a tutor, process facilitator, and metacognitive coach
- The use of reflection on practice

about power (to make decisions about the previous three)

- Student should have more responsibility to direct their own learning

Universal Methods

1. Use authentic and meaningful real-world problems that fit within the curriculum for the discipline and encourage cross-discipline thinking. There are four design principles: the problems should be holistic, practice-based, ill-structured, and contemporary.

2. The tutor facilitates the development of the learner's metacognitive processing and problem-solving skills.
    - Adjust the level of guidance and support to match the needs of the learner.
    - Provide instructional materials related to the development of anticipated skills along with the preliminary content materials at the start of the problem activity.
    - Remove the tutor from the role of information provider as much as possible.
3. Use authentic assessment practices to validate the learning of content, problem-solving skills, and higher-order thinking skills (including self-direction).
    - Each student self-assesses on her or his effectiveness as a researcher and as a contributor to the problem-solving process of the group.
    - Students also reflect on process and knowledge gains and the integration of that knowledge with prior knowledge.
    - The proposed solution to the problem is assessed on criteria (often developed by the students) such as completeness, accuracy, and viability.
    - Learner motivation and collaboration are assessed.
4. Use consistent and thorough debriefing activities to consolidate key concepts learned from the experience.

Situational Principles

- When students are not familiar with the PBI process, then the teacher must invest considerable effort in managing the learning process for and with the students, as well as providing answers to questions. Use instructional simulations and cases before using a PBI 'problem' (to help prepare students to become more self-regulated/independent in their thinking and able to work collaboratively).
- The choice of the problem and the level of complexity should always be adjusted to the developmental level (or maturity) of the students.
- When a class is large, the instructor should create smaller groups and allow those teams to stay together for multiple problems so they can realize the benefits of collaborative effort.
- When a class is large, the instructor should use strategies for forming and managing cooperative groups within a large class.
- A large class will need a greater quantity of resources.

— CMR & ACC

Problem-Based Approach to Instruction

This chapter examines the problem-based learning approach to instruction from the perspective of instructional design theory and synthesizes the current knowledge and theory into some universal methods, situational methods, and principles for a theory of problem-based instruction (PBI).* The history of public education provides many examples of changes in philosophy and shifts in the influences of society on instructional practice. During the transition from the Agrarian Age to the Industrial Age, public education adopted a teacher-centered approach to instruction. In the current Information Age (or knowledge age), in which knowledge work has replaced manual labor as the predominant form of work, methods of instruction that revolved around sorting students are giving way to methods that revolve around helping all learners to reach their potential. One instructional innovation that has persisted and continues to prosper is PBI.

PBI evolved as a pragmatic solution to perceived problems with the traditional approach to medical education during the transition from the Industrial Age to the Information Age. During the 1960's changes in the field of medicine, including new diagnostic tools, new medicines, and new treatments, were entering the knowledge base at an ever-increasing rate, causing a disconnect between knowledge acquired through instruction and application of that knowledge in

* Editors' note: Based on common definitions of the terms, the difference between PBI and PBL is that PBL is the learning that results from PBI

practice. Howard Barrows, one of the innovators of PBI in medical education at McMaster University in Canada, noted:

> … studies of the clinical reasoning of students…suggested that the conventional methods of teaching probably inhibit, if not destroy, any clinical reasoning ability (Barrows & Bennett, 1972) …[and] that students had forgotten their freshman [course content] by the time they reached their clinical course as juniors.... [This] led to my design of a method stressing development of the clinical reasoning or problem-solving process. (Barrows, 1996, p. 4)

Simply stated, the process of patient diagnosis (doctor's work) was based on a combination of the hypothetical-deductive process and expert knowledge in multiple domains – the rapidly changing knowledge base was not reflected in the 'traditional' lecture approach and thus lacked application. The tutorial process resulting from these insights (Barrows, 1988; Barrows, 2000) provides a specific instructional method with well-articulated procedures, as well as a philosophy for structuring an entire curriculum to promote student-centered, multidisciplinary education and lifelong learning in professional practice (Wilkerson & Gijselaers, 1996).

In North America and around the world, the use of PBI continues to expand in elementary schools, middle schools, high schools, universities and professional schools (Torp & Sage, 2002). The Illinois Mathematics and Science

Academy (http://www.imsa.edu/center/) has been providing high school students with a complete PBI curriculum since 1985 and has expanded to serve thousands of students and teachers as a center for research on PBI. The Problem-Based Learning Initiative (http://www.pbli.org/) in Springfield, Illinois, has developed curricular materials (i.e., problems) and teacher-training programs in PBI for all core disciplines in high school (Barrows & Kelson, 1993). PBI is widely used in other disciplines within medical education (dentists, nurses, paramedics, radiologists, etc.) and in content domains as diverse as MBA programs (Stinson & Milter, 1996), higher education (leadership education) (Bridges & Hallinger, 1996), chemical engineering (Woods, 1994), economics, (Gijselaers, 1996), architecture (Kingsland, 1996), and pre-service teacher education (Hmelo-Silver, 2000; 2004). This list is by no means exhaustive, but is illustrative of the multiple contexts in which PBI is being utilized.

As the Information Age continues to impact an ever-increasing number of jobs and disciplines, the skills developed through the PBI approach, such as self-directed, self-regulated, and lifelong learning, assume greater importance and a much larger audience. The significant impact on learning of metacognitive processing, self-monitoring, self-efficacy, volition, and motivation is stressed in the literature on self-regulated learning (Schunk & Zimmerman, 1998; Zimmerman & Schunk, 2001). Schunk (2001) describes self-regulated learning as, “learning that results from students’ self-generated thoughts and behaviors that are systematically oriented toward the attainment of their learning goals" (p. 125). The skills necessary to be successful in a broad range of disciplines can be refined through repeated experiences in problem-solving situations and the systematic construction of an integrated knowledge base.

The Wingspread Conference (1994) asked leaders from state and federal governments and experts from corporate, philanthropic, higher education and accreditation communities for their opinions and visions of undergraduate education. The conference reported the need to address specific problems in complex, real-world settings, and this clearly resonates with the philosophy of problem-based learning and reinforces the importance of explicating a viable design theory for this approach to instruction.

What is PBI?

Problem-based approaches to instruction are rooted in experience-based education (see Chapter 7). Research and theory on learning suggest that by having students learn through the experience of solving problems, they can learn both content and thinking strategies. PBI is facilitated problem solving where student learning is organized around a complex problem that does not have a single correct answer. PBI typically starts with the presentation of the problem rather than a lecture or reading assignment intended to impart discipline-specific knowledge to the student. Students engage with the problem, generate ideas and possible solutions, determine what they currently know and do not know, establish learning goals, conduct research to acquire the knowledge and skills needed to develop a viable solution to the problem, reflect on the problem utilizing the new information, and reflect on their problem-solving process (Savery & Duffy, 1995). As the learners work through the hypothetical-deductive reasoning process, the tutor provides support for their learning and their development of metacognitive skills.

For example, first-year medical students meet with their tutor to discuss the patient named Mary described as a 56 year old female complaining of recent numbness in her right leg and sporadic blurred vision. The students draw from their prior knowledge and suggest possible explanations for Mary's symptoms. Students must ask for more information, and in response to their specific questions the tutor provides whatever information is available in the case files – for example, current blood pressure, family medical history, any medications, etc. These are the protocols that a physician would follow to diagnose the problem – this is applied practice in the discipline. When the students reach the point where they need more information, they itemize what they need to know, and members of the team take ownership for researching the questions and reporting back to the group. This problem-solving cycle (Barrows' term is hypothetico-deductive) continues until the team has agreed upon a diagnosis and course of action for the patient, Mary. The tutor (this role is discussed more fully later) guides the team through a debriefing of the learning experience in which the members assess their team process, their individual process, and the utility/accuracy of the resources used to arrive at their solution. Critical learning outcomes from the problem of Mary are identified, and knowledge gains are consolidated.

PBI is sometimes confused with a case-based approach. While there are several similarities between a problem-based approach and a case-based approach, there are significant differences, as cleanly explicated by Williams (1992). The fundamental difference lies in the purpose of the instruction. If the intent is to provide vivid and complex exemplars that assist the learner in forming conceptual relationships with content that may be abstract, then well-written cases are an excellent vehicle. A well-structured case study will include the critical information needed to arrive at a pre-determined conclusion. With most case studies there is one right answer (and some close answers) and the learning task for the student is to pick up on all the clues that are important (and avoid the red herrings). Walking this carefully groomed path from situation presentation to solution provides the students with an engaging experience that they can refer back to should they encounter a similar set of circumstances in their future practice. A problem-based approach is different in that the nature of the problem selected is less clearly defined – part of the task for the learner is to refine the general problem into component parts – and the solution or range of solutions is not pre-determined. By utilizing current resources, solutions to a problem can change over time.[1]

Although the PBI approach was significantly refined by the work of Barrows and others in the context of medical education, the audiences for PBI are not limited to post-graduate professional education. Torp and Sage (2002), who have done considerable work with high school students at the Illinois Mathematics and Science Academy (http://www.imsa.edu), describe PBI (or PBL) as follows:

> PBL provides authentic experiences that foster active learning, support knowledge construction, and naturally integrate school learning and real life; this curriculum approach also addresses state and national standards and integrates disciplines. The problematic situation offers the center around which curriculum is organized, attracting and sustaining students' interest with its need for resolution while exposing multiple perspectives. Students are engaged problem solvers, identifying the root problem and the conditions needed for a good solution, pursuing meaning and understanding, and becoming self-directed learners. Teachers are problem-solving colleagues who model interest and enthusiasm for learning and are also cognitive coaches who nurture an environment that supports open inquiry. (p. 15)

[1] A colleague teaching in the School of Law often clips a news item from the newspaper or videotapes an item from TV news and uses it as the catalyst for class discussion. These spontaneous problems have multiple possible solutions and provide students with an authentic learning experience – sharpening the skills they will need once they complete their degree.

While individual instructors may use problems to provide a stand-alone learning experience, the greater benefit for the learners occurs when the entire curriculum is problem-based. As is discussed later in this chapter, a problem-based curriculum provides students with a sequence of carefully designed problems (Barrows, 1986) that "crisscross the landscape" (Spiro, Feltovich, Jacobson & Coulson, 1991) of knowledge and skills determined by a careful review of the domain and the problems/issues identified by expert practitioners (Macdonald, 1997; Stinson & Milter, 1996).

Cognitive theories of learning* may be used to further explain the success of the PBI approach. Resnick (1989) suggests three interrelated cognitive theories: 1) learning is a process of knowledge construction, learning occurs not by recording information but by interpreting it, 2) learning is knowledge dependent, people use current knowledge to construct new knowledge, and 3) learning is highly tuned to the situation in which it takes place. Each of these cognitive theories is reflected in the PBI theory.

Learning is a process of knowledge construction: Duffy and Cunningham (1996) note the importance of active learning, of both understanding and challenging the learner's thinking and the historical use of inquiry-based approaches as a stimulus for learning, including Piaget's term of *disequilibration*

* Editors' note: Note that these are learning theory, not instructional theory.

and Dewey's term of *perturbation*. They discuss differences between cognitive constructivist theories of individual cognition and social constructivist theories of socially and culturally situated cognition (Katz & Chard, 1989; Moll, 1990; Vygotsky, 1978; Wertsch, 1991). It could be argued that both aspects of constructivism are necessary components of PBI that contribute to an effective learning experience.

Learning is knowledge dependent: Research by Glaser (as cited by Resnick, 1989) suggests that both reasoning and learning are knowledge driven and, more specifically, that "Those who are knowledge-rich reason more profoundly. They elaborate as they study and thereby learn more effectively. Knowledge thus begets knowledge" (p. 2). Research on problem solving further supports the significance of knowledge and experience as critical elements in effective problem analysis and the development of a viable solution (Jonassen, 2004).

Learning is highly tuned to the situation: Cognitive flexibility theory (Spiro, Feltovich, Jacobson & Coulson, 1991) suggests that using complex, messy, real-world problems helps students to transfer the knowledge and skills they learn to future complex, real-world problems and learn to apply the knowledge and skills to novel or ill-structured problems (Jonassen, 1997). In a similar vein, Bransford, Brown and Cocking (2000) identify PBI as a strategy to encourage transfer of learning between school and everyday life (p. 77). Situated cognition theory (Brown, Collins, & Duguid, 1989) identifies the importance to learning of using ill-defined, authentic problems.

Thus, these three areas of learning theory collectively underscore the use of a problem-based approach.

PBI has been adopted by different disciplines and, in the process, has been changed in both small and substantial ways to accommodate local conditions. This has led to some misapplications and misconceptions of PBI, and consequently certain practices that are called PBI or PBL do not achieve the anticipated learning outcomes. In the next section, I describe universal principles that must be applied in all uses of the PBI approach.

Universal Principles and/or Methods for PBI

There is remarkable consistency and convergence among researchers and practitioners concerning guiding principles for the design of effective PBI. The four main clusters of principles that will be unpacked in the following sections are:

1) Select problems that are authentic and fit within the curriculum for the discipline and encourage cross-discipline thinking.
2) The role of the tutor is to support the development of the learner's metacognitive processing skills and the learner's expertise as a problem-solver.
3) Use authentic assessment practices to validate the learning goals.

4) Use consistent and thorough debriefing activities to consolidate key concepts learned from the experience.

Principle 1. Select problems that are authentic and fit within the curriculum for the discipline and encourage cross-discipline thinking.*

PBI is designed to support the development and refinement of higher-order thinking skills. It is not well suited as an instructional strategy for teaching basic skills. The PBI approach requires the selection of problems for which the learners (even young learners) already have some knowledge gained from lived experience, so that the application of this prior knowledge with the knowledge acquired through research and problem-solving can generate a deeper understanding.[2] Barrows (1996) explains the use of authentic problems in medical education as,

> [The problem] represents the challenge students face in practice and provides the relevance and motivation for learning. In attempting to understand the problem, students realize what they will need to learn from the basic sciences. The problem thus gives them a focus for integrating information from many disciplines. (p. 6)

Savery and Duffy (1995) proposed eight design principles for PBI,

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* Editors' note: Is this instructional theory (how to teach) or curriculum theory (what to teach)? Or some of both? What layer of design is this in?

[2] It is common practice in medical schools using the PBI approach to present first-year medical students with a problem on their first day of class.

including one for authenticity:

> ***Design an authentic task.*** An authentic learning environment does not mean that the fourth grader should be placed in an authentic physics lab, nor that he or she should grapple with the same problems that an adult physicist deals with. Rather, the learner should engage in scientific activities, which present the same "type" of cognitive challenges. An authentic learning environment is one in which the cognitive demands, i.e., the thinking required, are consistent with the cognitive demands in the environment for which we are preparing the learner (Honebein, et al., 1993). Thus we do not want the learner to learn about history but rather to engage in the construction or use of history in ways that a historian or a good citizen would. Similarly, we do not want the learner to study science -- memorizing a text on science or executing scientific procedures as dictated -- but rather to engage in scientific discourse and problem solving. (p. 33)

Stinson and Milter (1996) implemented their PBI approach with cohorts of MBA students, and the process they used to select problems began with the basic question, “What do we want our students to know, and know how to do, as they leave our program?” To answer that question, they tasked participating faculty with developing a list of the minimum acceptable conceptual knowledge and skills that all MBA graduates should have in their particular discipline area. They asked business people who would be hiring the new graduates what they expected the new graduates to know and be able to do. Finally they conducted a futures analysis to identify short-term and long-term skills and knowledge that graduates would need to be successful. This process resulted in a dozen 'meta-outcomes' and over 150 specific learning outcomes. It could be argued that this exercise to develop clearly defined learning outcomes would be a beneficial activity for any instructional program. To guide the development of problems that would meet the meta-outcomes, they followed these design principles:*

1. *Learning outcomes should be holistic*, not divided by narrow disciplinary boundaries. Rationale: to avoid limiting potential learning, and to encourage taking multiple perspectives.
2. *Problems should mirror professional practice.* Rationale: to increase knowledge transfer.
3. *Problems should be ill-structured.* Rationale: real-world problems are messy and learners need to develop the ability to make sense of ambiguous, ill-defined situations.
4. *Problems should be contemporary.* Rationale: learner engagement with the problem is increased when current situations can be drawn into the discussion. (See also Savery, 1999, and Chapman, 2000.)

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* Editors' note: Are these instructional theory (how to teach) or curriculum theory (what to teach)? Or some of both? What layer of design are these in?

In K-12 public education the selection of an instructional problem is influenced by the state mandated curriculum, learning standards, standardized tests, and members of the local community. Teachers should select problems that provide for integration across disciplines and for demonstrations of learning through projects, presentations, or other means that would be appropriate or realistic for the problem situation. The 'problem' becomes the focus of the instructional unit. The role or perspective of the student with respect to the problem becomes a variable. For example the 'problem' of the endangered spotted owl in old growth forests is viewed differently from the perspective of the lumberman, legislator, environmentalist, and retailer in the local community (Torp & Sage, 2002, pp. 16-18). Also, Wilkerson and Gijselaers (1996) argue that the types of problems selected should represent those that practitioners of the discipline encounter on a regular basis.

In medical education, Macdonald (1997) reported on the process used to select appropriate problems from the large medical education curriculum. Given the huge number of medical conditions or ailments that could be taught, the task was to select problems that had educational importance (defined as clinical logic, prototype value, urgency, treatability, and interdisciplinary input) and also were typical of the medical problems that were prevalent in the general geographic region. The first step was to obtain and sort the data to identify the major health problems in the area. Macdonald notes that these data are not always available in under-developed countries and that countries with advanced health care systems often record the diagnosis but not the health problem (i.e., emphysema was diagnosed, but the cause – smoking – was not identified). These health problems were further filtered based on the criteria of magnitude, fatality rate, quality of life, duration/severity, urgency, preventability, diagnosibility and treatability. Thus, the better problems to include in the curriculum were "common, severe problems, for which effective interventions exist." (p. 98).

Thus, selecting problems for MBA students, K-12 students and medical students incorporates the same four design principles: holistic (interdisciplinary), practice-based (authentic), ill-structured, and contemporary. (See also Schmidt and Moust, 2000, for a taxonomy of problems used in a PBI curriculum).

To summarize, the literature offers the following guidance for instructional designers on the task of PBI problem generation or selection:

1. The problem should be grounded in the knowledge and skills mandated by the curriculum.
2. The problem should engage the learners in a significant aspect of the content within the discipline and/or across disciplines or domains of knowledge.
3. The problem should be authentic, contemporary and relevant.
4. The problem should require learners to utilize the same knowledge, skills, and attitudes as would be required in a real-world setting.

5. The problem should be complex enough and large enough to challenge the learners and require contributions from all members of the team.
6. The problem should be ill-structured with missing or contradictory information.
7. Provide instructional materials related to the development of anticipated skills along with the preliminary content materials at the start of the problem activity. Learners will note the existence of the materials and return to them when they have a need and purpose for learning the skill.

Principle 2. The role of the tutor is to support the development of the learner's metacognitive processing skills and the learner's expertise as a problem-solver.

Arguably the most critical element in the successful implementation of PBI is the ability of the tutor to function as a facilitator of learning rather than as a provider of content. Barrows (1988) provides extensive detailed guidance on the responsibilities of the tutor and strategies for managing productive group sessions. He summarizes 13 general principles for tutorial teaching that could be applied in most (if not all) tutorial sessions with learners engaged with a PBI experience (pp. 18-20). With respect to managing the PBI sessions Barrows (1988), states that the tutor needs to "keep the learning process moving, to make sure that no phase of the learning process is passed over or neglected and that each phase is taken in the right sequence" (p. 6).* The tutor needs to be sure that all students are involved in the group process, that none is allowed to withdraw from the discussions, and that none is allowed to dominate the discussions. The tutor should also be able to modulate the complexity of the problem to avoid extremes of boredom or frustration. (p. 10)

With respect to developing knowledge in the domain, Barrows states:

> The tutor must probe the student's knowledge deeply … [and] constantly ask "Why?" What do you mean?" "What does that mean?" "How do you know that's true?"… again and again until the student has gotten down to the depth of understanding and knowledge expected of him and has brought out all he knows (often more than he realizes he knows). The tutor must **never** let ideas, terms, explanations or comments go unchallenged or undefined … You cannot assume that a student correctly understands a concept or entity because he can use the label correctly. (p. 7)

Therefore, the tutor provides the initial guidance and support with process skills, including metacognitive modeling for individuals and the entire group, while members of the group work cooperatively on the problem. Over time and with experience in PBI, learners take over the tutoring function to support each

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* Editors' note: What layer of design are these in?

other by sharing knowledge they have acquired related to understanding and solving the problem (peer tutoring).

The role of the tutor is so critical to the success of the PBI approach that it is worthwhile at this point to distinguish between a tutor and a coach. Collins, Brown, and Newman (1989) describe a cognitive apprenticeship model of teaching in which the teacher serves as a coach who provides the learners with hints, feedback, modeling, reminders, scaffolding, and increasingly challenging tasks with the goal of bringing the performance of the apprentice closer to that of the expert. The teacher/coach models the thinking strategies of an expert in a realistic context, and invites the apprentice to articulate their reasoning, knowledge, or problem solving processes. Thus, a teacher applying a cognitive apprenticeship instructional strategy guides the learner to a level of expert knowledge in the content domain by modeling problem solving strategies within the domain (i.e., watch how 'I' do this), coaching the learner on control strategies (i.e., metacognitive monitoring) and learning strategies for adding new knowledge and skills, and gradually fading into a minor role as the learner gains confidence and competence. The significant facts, concepts, procedures, principles, rules, and attitudes in the domain are learned in the context of their use (see also situated cognition, Brown, Collins & Duguid, 1989).

The tutor in PBI differs from the cognitive apprenticeship coach in the areas of status and ownership of the learning process (Savery, 1996; 1998). The coach, being an expert in the content/skill domain, knows how to perform the task better than the learner. The coach's suggestions can be highly directive (didactic show and tell) or highly reflective (what would you do in this situation?). The tutor in PBI may or may not be an expert in the domain. In fact, Barrows (1988) argues the tutor should not be a content expert. In any case the tutor does not answer content questions. Rather the tutor operates at the metacognitive level to direct student thinking in the use of productive problem solving strategies. Instead of telling the learners they are missing important facts, the tutor asks the learners if they have all the facts they need to proceed. Group members select areas for further research and report their findings back to the group in an agreed-upon timeframe with an emphasis on how this information is related to the development of a solution to the problem. With younger students in a PBI activity, some limited direct instruction may be necessary* (Torp & Sage, 2002), but the focus on cognitive coaching is critical.

To summarize guidance on the role of the tutor in PBI, consider the following:

1) The tutor repeatedly asks questions to probe the depth of the learner's knowledge.
2) The tutor focuses on group process to ensure that ALL learners in the

* Editors' note: See Chapter 5.

group are involved and articulating their understanding of the problem, the problem-solving process, and the proposed solutions.

3) The tutor prompts learners to think at a metacognitive level and supports the development of self-regulated learning.
4) The tutor avoids the role of information provider as much as possible by making information resources available and promoting collaboration with teammates who may have the necessary skill or knowledge.
5) The tutor senses when the problem is either boring or frustrating the learners and modulates the problem by providing guidance to make the problem more manageable.

Principle 3: Use authentic assessment practices to validate the learning goals.*

How do we assess individuals working in a group on a problem that is holistic, practice-based, ill-structured, and contemporary? Assuming Principle 1 (selection of problems) has been honored, and assuming that the tutor has been effective in facilitating the group problem-solving process, then we should be able to assess 1) content knowledge and skills within a domain, 2) problem-solving skills (process and reflection), and 3) the development of higher-order thinking skills (metacognitive).

* Editors' note: This is student-assessment theory, which should often be integrated with instructional theory, especially in the Information-Age paradigm of education.

A well-designed problem contains the *criteria* for presentation of the proposed solutions. In a medical context, it could be a formal written report (using standard hospital forms) detailing diagnosis and treatment for the patient that has been decided upon and agreed to by all members of the group. The group members would then explain to the tutor (or an expert panel) the parameters of their solution and their reasoning in arriving at the solution. The proposed solution would then be compared with the opinions of an expert confronted with the same problem or the actual medical case that served as the basis for the problem. Similarities and differences would be discussed to further clarify the understanding of each member of the group to ensure that the critical concepts were understood.

For a problem related to water quality prepared by high school students, the proposed solution could be a report identifying the sources of pollution and strategies for reducing future pollutants. The criteria for the presentation of the proposed solution could include visual aides, graphs, a PowerPoint presentation or some other media to assist students in developing skills with presentations. A variation on this approach might be a report composed by the learners and sent to either a politician or perhaps a company causing water pollution.

Formative assessment of the viability and utility of information provided by members of the group (obtained through independent research) is an on-going component of the group problem-solving process. All group members are expected to take responsibility for researching information to bring back to the group and explain how the information they have retrieved contributes to the development of a possible solution. All members of the group are expected to assimilate the content through discussions with their team members and experts (textbooks or humans). Individuals are expected to clearly articulate their understanding of the content addressed by the problem. To assess how individuals within the group are assimilating the collected information, the tutor can ask any student at any time to summarize the collective learning of the group related to the problem. To ensure that both the group and individuals within the group have arrived at the intended learning outcomes, the important learning points are assessed through the debriefing process. There is no ‘standardized test’ to assess the learning outcomes from a given PBI experience.

Torp and Sage (2002) describe multiple assessment strategies that can be used within the PBI approach. They note in particular the use of the “facets of understanding” (Wiggins & McTighe, 1998) approach to assess learner understanding, and the alignment with state and national standards that is an increasingly important element in the accountability of public education. It is beyond the scope of this chapter to provide a review of the six facets of understanding described by Wiggins and McTighe and their theoretical and practical implications for curriculum, assessment and teaching. The reader is encouraged to review in detail their conceptual framework and consider its relationship with PBI.

Summative assessments are appropriate with PBI. However, to be authentic, the test should assess the student's ability to use reference and resource materials (which experts do in practice) to develop a problem solution, as well as their knowledge of concepts, theories and terminology within the domain. Summative assessment, such as medical board exams, should be taken after a complete curriculum of problems has been concluded and the content knowledge to be covered by the test has also been covered by the sequence of problems. Summative assessment in the K-12 context is more complicated given the breadth of basic skills that are developed during this time span, the state-specific curriculums that determine the content to be taught, and the various standardized exams used to determine high school completion. Until authentic assessment as described above becomes more widely accepted in public education, it will be challenging to gauge the impact of PBI curricula on student learning.

One of the more challenging aspects of PBI to assess with any certainty is the growth of self-regulation in learning by the students. It is naïve to assume that this growth would be evident after only a few PBI sessions. Rather it is an incremental change over time in the ability of the learners to express their thinking clearly, challenge the thinking of others with insightful comments, conduct effective independent research, and share that with the others in the problem-solving group. During the PBI sessions the tutor is continuously monitoring and assessing the abilities of all the learners in the group. This assessment includes the direct questioning (knowledge probes) by the tutor of all members of the group. This probing reveals the depth of the individual's understanding and also their awareness of their own thinking and the strategies they use to obtain and process information. Similarly, the tutor probes to assess the depth and quality of the independent research presented by individuals.

To summarize guidance on the use of authentic assessment of PBI, consider the following:

1. The instructor/tutor must clearly understand the intended (or anticipated) learning outcomes associated with the problem presented to the learners. The assessment strategies used must align with these intended outcomes.
2. Summative assessment can occur at the end of the problem-solving cycle as student teams present (in whatever format) their proposed solution(s) to the problem. Expert review or comparison with previous/recommended solutions will provide a measure of the accuracy of the group efforts to solve the problem.
3. Formative assessment can occur at any time in the PBI cycle. Barrows (1988) suggests having learners put their name on a page and write about their current understanding of the problem and where the team is in the process of developing a solution. This will help ensure that all students are attending and actively processing information.

Principle 4: Use consistent and thorough debriefing activities to consolidate key concepts learned from the experience.

PBI could be considered a form of experiential learning theory (Kolb, 1984; Lindsey & Berger, Chapter 7). Instruction using experiential learning is a cyclic process of setting goals, followed by thinking, planning, experimenting and decision making, followed by action, followed by observing, reflecting and reviewing, followed by a bit more thinking, decision making and sometimes adjusting goals, followed by more action, and so on. This approach utilizes the participants' experience and their reflection about that experience, rather than lecture and theory as the means of generating understanding and transferring skills and knowledge. Most PBI activities involve a similar cyclical process; however, properly implemented there is greater emphasis on the post experience debriefing activity. Students of all ages will be tempted to skip this reflection step, and unfortunately many teachers will be tempted also to just enjoy the moment of satisfaction that comes from completing the process and arriving at a solution. This would be a mistake, as the debriefing process is critically important to get the learners to recognize, verbalize, and articulate what they have learned, and to integrate the new information with prior knowledge.

Simulations are another form of experiential learning (see next chapter), and the need for debriefing is considered critical to the successful utilization of a simulation for learning. According to Thiagarajan (1993), "People don't learn from experience unless they take time to reflect on that experience, derive useful lessons from it, and identify situations to transfer and apply these lessons" (p. 45). Thiagarajan proposed a sequence for conducting a debriefing that should include: emotional ventilation (let off steam if the experience has been intense), drop roles (return to reality), tell the truth (if deception was part of the simulation), share insights (different perspectives of participants), generate hypotheses (examine cause-effect relationships), transfer to the real world, second thoughts (what to do differently?), and what is (to extrapolate beyond the context of the experience). These elements provide guidance for debriefing in a PBI situation. (See also Steinwachs, 1992, and Peters and Vissers, 2004, for additional information on debriefing activities.)

Barrows (1988) stressed the critical importance of debriefing and evaluation by the learners once the group has finished its work on the problem. He suggests the tutor ask questions such as: "What have we learned with this problem?" "What new facts or concepts?" and, "How has our work with this problem extended our knowledge of [XYZ]?" (p. 40).

To summarize the guidance for instructional designers on the debriefing process, consider the following:

1. The purpose of the debriefing process is to help the learners to recognize, verbalize, and consolidate what they have learned, and to integrate any new information with existing knowledge.

2. The job of the tutor/debriefer is to ensure equal voice for all participants, so be careful to listen to all members and to ask all members for their opinions and comments.*
3. Follow established debriefing protocols. Know the generic and specific questions to be asked to guide the debriefing session. Prepare question ideas/topics to ensure that you (as debriefer) remember all the learning that has been discussed in the PBI activity.
4. Ask questions that encourage learners to fit the new knowledge into existing schemas.
5. Encourage learners to diagram (or list) what they have learned using concept maps – provide necessary materials.

Situational Principles and/or Methods for PBI

Given the scope of the adoption of this instructional approach, it is challenging to describe specific situations and methods for implementing PBI. As noted earlier, PBI is widely used in the preparation of professionals in disciplines such as medicine, business, architecture, engineering, law, and in a variety of other disciplines where there is a clear need to integrate theory and practice. There is an established body of research on the effectiveness of PBI with adult learners, and with the growing sophistication of online learning environments studies are

* Editors' note: What layer of design is this in?

underway to adapt PBI for this new delivery format. There is also a growing body of research on implementing PBI with younger learners (high school and elementary school). This section will expand on the principles listed above and examine some situations that may impact on the methods used in PBI.

Situation 1. Learners' lack of prior experience with PBI

Teaching with PBI requires students to verbalize their understanding, work in collaborative teams, and conduct independent research. These skills are articulated in all K-12 and professional curriculums in some form or another, but they are often treated as separate skills, rather than integrated with an approach such as PBI. If students are not familiar with the PBI process,* the teacher must invest considerable effort in scaffolding their learning experience (White, 2001). If previous educational experiences have 'trained' learners to be teacher dependent, [†] most will be uncomfortable and resistant to an instructional environment that asks them to 'think' for themselves. Thus, the tutor should determine the level of familiarity with PBI (and the sub-skills noted above) as part of a learner analysis and adjust the level of guidance and support to match the needs of the audience. This is consistent with the basics of instructional design and the learner analysis phase of the ID process. Learners with minimal PBI experience would be taught process skills (how to formulate and articulate ideas

* Editors' note: This is the situationality.

[†] Editors' note: This is another situationality.

and opinions, how to work collaboratively, and how to be an effective researcher) and be directed to problem-specific resources to lead them to the intended learning outcomes. Less support would be necessary as the students grow as self-regulated learners and gain experience with the expectations of the tutor and the PBI approach. Using instructional projects, simulations or case studies to develop the necessary skills will help prepare students to work effectively on ill-structured problems.

The choice of the problem and the level of complexity should always be adjusted (neither too simplistic nor too predictable) for the age and developmental characteristics of the intended audience.* Aligning the problem with curricular goals for the grade level/discipline and empowering the tutor to adjust the level of complexity during the problem-solving process will reduce this potential problem situation. Remember that learning is cumulative, and the same 'problem' or a variation can be re-visited at a future time. The spiral curriculum approach (see also Elaboration Theory as described by Reigeluth in Chapter 18 of Volume II) applies when a PBI approach is followed and a change in problem conditions will challenge the learner to apply previous understandings to new circumstances, thus adding depth to their knowledge base.

* Editors' note: Age and developmental characteristics are additional situationalities.

Situation 2. Using PBI with large class sizes

Barrows (1988) acknowledges the challenges of large-group tutoring and suggests two strategies. The first strategy, used during both large and small group meetings,* is to have students sit facing each other and the tutor rather than having the tutor face the whole group. This allows students to interact with each other and removes the instructor from the dominant position. The second strategy, used primarily with large groups, is to have a seating chart (possibly with photographs) and expect that at each session the students will sit in the same place so the tutor can call on them by name. He also suggests with large groups to provide each student with a copy of the case (problem) before the class session with the tutor. At that session the questions from the tutor are more general – "What is going on with this problem?" or "Who wants to start off?" (p. 47). Barrows expects that the tutor will ask probing questions of all students and work to ensure that all are involved, but with a large number of students it may be difficult to engage with every student each session. Over time, as the tutor begins to identify the students who are on target and the one's who are having difficulties, he/she can focus on the students that seem to be in trouble. PBI with large classes is a challenge for even the most experienced tutors and is not recommended as the preferred approach. A small-group format (5-7 members) appears to be the most effective

* Editors' note: If the method is for both large and small groups, is it another situationality?

teacher-student ratio.

The small-group format allows every member to be heard in discussions and to engage with a significant portion of the problem. The instructor will need to create small groups (within the class) and allow those teams to stay together for multiple problems so they can realize the benefits of collaborative effort. Multiple strategies for forming and managing collaborative groups within a large class (balanced by variables such as gender, age, experience with PBI, skills, etc.) have been well documented (Kagan, 1992; Rangachari, 1996) and are applicable in the context of a PBI approach.

Stinson and Milter (1996) taught a single class of 30+ MBA students who worked in small groups on the same problem. These small groups worked in parallel on different aspects of the problem so multiple sets of resources (textbooks, articles, charts etc.) could be shared between groups. With multiple groups working on the same problem, it may be necessary to duplicate a set of resources for each team to support their initial research efforts. For example, multiple groups working on a problem related to flooding or wetlands pollution or hazardous waste would each receive a packet of articles, reports, and audio/video materials to review and assess prior to refining their specific research questions.

Implementation Issues

Embedded within the situations listed above are some implementation issues worthy of note.*

1. **Commitment of the instructor and the organization.** PBI will not work if the instructor is not committed to its success. If the organization does not believe that significant learning can occur using a learner-centered rather than a teacher-centered instructional format, then PBI will not succeed. Adopting and implementing PBI, particularly in K-12 schools, requires extensive planning, discussion and communication among teachers, administrators, parents, and students. For a detailed examination of the process of adoption of PBI at the program level, see Anderson (1997) or Conway and Little (2000) or Duch, Groh and Allen (2001).

2. **Commitment to the complete PBI process.** PBI should not be attempted without a complete understanding of the process and how it works. Boud and Feletti (1997) note that PBI can be confused with simply teaching some problem-solving skills or adding a problem activity to a teacher-centered instructional environment and rewarding the student product rather than the learning process. To be effective, the problems used in PBI need to be carefully selected and sufficient time and resources need to be provided to students and tutors to ensure that the steps in the learning process from problem introduction to debriefing and evaluation of learning have been thoroughly completed.

* Editors' note: As you read what follows, try to determine if this is implementation theory or some other kind of knowledge.

3. Shift of teachers' pedagogical beliefs. Relatively few professional educators (classroom teachers, college professors and practitioners in disciplines) have experienced PBI as students. It is axiomatic that we tend to teach as we were taught, so this lack of exposure to a problem-centered instructional methodology will require a sincere effort on the part of tutors to shift their epistemological and pedagogical beliefs to become effective implementers of PBI. Professional development workshops are available for faculty and teachers (e.g., http://www.udel.edu/pbl/ and http://www.imsa.edu/), and there are several excellent 'how to' books listed in the references.

4. The physical space. The traditional classroom can impose physical constraints on the implementation of PBI. The ideal room for practicing PBI would have large writing surfaces on all four walls, large tables rather than small desks, multiple computers in the room, and a well-stocked library nearby. Most classrooms were designed for the presentation of information rather than the generation of ideas and the resolution of complex, ill-structured problems. Re-design of the learning space to accommodate productive small group sessions is an important consideration when adopting PBI. Any writing surface will do (flip charts, white boards, black boards), as long as it enables group members to record and view their ideas and share information, and can remain in place for the duration of the problem-solving activity. PBI is not quiet. Students will debate ideas and information (loudly) before they arrive at clarity and consensus.

Consider this also when designing the learning space.*

Summary

Which professionals are the most respected and rewarded by society? Arguably, doctors, lawyers, scientists, engineers, architects. What do these professionals do – they diagnose problems and develop solutions. Many of these professions have adopted a PBI approach to educate new members of their profession. If PBI is appropriate for the most complex knowledge domains, would it not also be appropriate for other areas that require diagnostics and the design of solutions? As has been highlighted in the previous sections, the PBI instructional theory is grounded on established theories of learning, and the mechanics of implementing the PBI approach have been well documented in learner populations ranging from elementary school students to medical students. In an effort to describe PBI as an instructional-design theory, the work of many experts in the domain has been presented and synthesized into what I hope will be viewed as a common knowledge base for the PBI approach to instruction. The reader is encouraged to follow the citations to the source articles for greater depth than it was possible to cover in this chapter.

The first two design principles that are keys to the success of a PBI approach are the selection of problems within the content domain – preferably

* Editors' note: Could these be viewed as preconditions for use of the theory? Could they also be viewed as implementation theory? What distinguishes the two?

within an entire PBI curriculum – and the ability of teachers to focus on the development of the learners' metacognitive skills and abilities. Since the amount of information (the knowledge base) in every discipline will continue to expand and change over time, teaching facts to memorize has marginal value. Facilitating the development of the learner's ability to be a critical thinker who is aware of gaps in their own knowledge and also able to apply strategies to remove those gaps has a higher rate of return.

The second pair of design principles focuses on assessment and debriefing to ensure the intended learning outcomes are realized. It is critical to complete the experiential learning cycle and debrief on the learning experience, thereby integrating facts and concepts acquired through the problem-solving process with existing knowledge and reflecting on the social, interpersonal, and other metacognitive skills that contributed to the success of the activity.

The design principles outlined in this chapter provide a framework for a host of methods and sub-methods that will increase the effectiveness of the instruction and the learning experience for the students. In summarizing PBI, Duch (2001) offers this advice:

> Writing PBL problems may be time-consuming, challenging, and sometimes frustrating. However, the process of thinking through the learning priorities of a course and finding, adapting, or writing complex, realistic materials to meet those learning priorities will

> change how an instructor views his or her course in the future. Any magazine or newspaper article, documentary, news report, book or movie that is seen will become possible material for new problems in the course. Faculty will gain a new appreciation for the concepts and principles that they teach, and the connections that should be made to concepts in other courses and disciplines (p. 53).

The contextually rich problems that you create will engage learner interest, provide direction and motivation, and because they are messy/ill-structured, they require that the learners filter the important issues and data from the unimportant or un-substantiated. These are some of the life-long learning skills that PBI helps the learner to develop.

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