The Problem-Based Learning Tutorial: Cultivating Higher Order Thinking Skills

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In today's information age, it is increasingly important to help learners develop higher order thinking skills as well as a flexible knowledge base. Research in cognitive science and education suggests that both of these aims can be achieved by having students learn through solving problems. Problem-based learning (PBL), with its emphasis on both strategies and content, is particularly well suited to achieving these aims. In PBL, student learning begins with a problem to be solved and includes cycles of reflection on the problem-solving experience. This paper will discuss the tutorial process in PBL and how it can be used to cultivate higher order thinking skills.

Introduction

The room is dark and quiet. The teacher slowly lights the candles in a mud pie as the students gather round. In a dramatic moment, he explains that as the room lights up with each additional candle, so will their knowledge of the human body brighten over the next few weeks as they work on their problem-based learning unit. Mr. R. is setting the climate for problem-based learning in his sixth-grade class. In this brief moment, he is laying the groundwork for these students' gradual construction of an understanding of the human body as they tackle the problem of designing an artificial lung. Using the problem-based learning (PBL) method, students will plan designs, set learning objectives, do independent research, and apply newly constructed knowledge to this complex problem. As they work on the problem, they learn to be independent thinkers and learners.

In today's information age, it is increasingly important to help learners develop higher order thinking skills as well as a flexible knowledge base (Simon, 1980). Many current educational reform movements recommend an increased emphasis on such thinking

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skills and knowledge construction (American Association for the Advancement of Science, 1993; National Council of Teachers of Mathematics, 1989; National Research Council, 1996; Resnick & Resnick, 1992). One of the most important points they raise is that students need to be active learners, which is best promoted by situating learning in real-world problems (Cognition and Technology Group at Vanderbilt, 1994; Collins, Brown, & Newman, 1989; Ferrari & Sternberg, in press; Kolodner, Hmelo, & Narayanan, 1996). This paper will discuss how the tutorial process in PBL can be used to cultivate higher order thinking skills.

Central to problem-based learning is having students grapple with ill-structured problems and reflect on their experiences. PBL, with its dual emphasis on strategies and content, is particularly suited to achieving this purpose. This approach has been used in a variety of settings from middle school to medical school (Barrows, 1985; Barrows & Kelson, 1995; Gallagher, Stepien, & Rosenthal, 1992; Hmelo et al., 1995; Williams, 1993). In PBL, students learn by solving authentic real-world problems. Because the problems are complex, students work in groups where they pool their expertise to deal with the complexities of the issues involved. Coaches guide student reflection on these experiences, facilitating learning of (a) the cognitive skills needed for problem solving, (b) the skills needed for collaboration and articulation, and (c) the principles behind those skills. Because students are self-directed as they manage their learning goals and strategies in order to solve the ill-structured problems used in PBL, they also acquire the skills needed for lifelong learning. PBL provides students with many opportunities to develop and practice higher order thinking skills.

Cultivating Higher Order Thinking Skills

Before we explore these claims, we need to specify what we mean by higher order thinking skills and consider how these can be taught. We begin by examining what we typically mean by thinking.

What Is Thinking?

Long ago, Dewey (1933) described four types of thinking, from the broadest to the most refined. The broadest sense of the term includes whatever passes through one's mind at any given moment; this sort of thinking is engaged in by everyone and is not highly valued. The second sense of thinking refers to what goes beyond direct observation; this sort of thinking is a little more abstract but includes imagination and fancies that may have no connection with even the most implausible reality. The third sense refers to belief in what seems probable but without consideration of its grounds; that is, a belief may be incoherent, may contradict the facts, or may have implications that the thinker would reject if she or he stopped to consider the question more deeply. Finally, in its most refined sense, thinking refers to reflective thought, and it is this latter sort of thinking that is commonly considered higher order thinking. It is this critical, metacognitive stance that Resnick (1987) alludes to in her monograph on higher order thinking skills when she describes such skills as involving effortful, nonalgorithmic thinking; complex, nuanced judgments; and consideration of multiple principles and solutions. She goes on to point out that higher order thinking is often done under conditions of uncertainty that require self-regulation of knowledge construction. According to Bruer (1993), higher order skills require a new synthesis of education and cognitive science that incorporates an extensive domain knowledge along with an appreciation of when to use that knowledge and includes metacognitive monitoring of performance needed for students to solve novel or ambiguous problems.

Programs to Teach Higher Order Thinking Skills

There are at least two key issues that go to the heart of many of the pedagogical methods that support this new educational synthesis. First, all of these methods emphasize learners constructing knowledge—although recently some educational researchers (Bereiter, 1994) have pointed out that what students construct often represents a mastery of knowledge that is semiautonomous of their own construction. For example, all students who correctly understand the Pythagorean theorem should construct equivalent knowledge of it, based on the mathematics involved. Of course, the individual paths to achieving that knowledge may be very different. Bereiter and Scardamalia (1996) argue that individuals must learn to view knowledge as a personal artifact that can be improved by productively reflecting upon the relations between existing theory and evidence. Second, these new pedagogies radically alter the roles of the student and teacher. The teacher is no longer the sole repository of knowledge but instead becomes a facilitator of knowledge construction. Now learners are responsible for actively constructing their knowledge, which necessarily depends on reflective, critical thinking about that knowledge. Truth and meaning come to depend on the coherence of the knowledge constructed, not its correspondence to the views of an external, unquestioned authority.

Several educational programs exemplify Bruer's (1993) new synthesis. For example, the success of the anchored-instruction approach exemplified by the "Adventures of Jasper Woodbury" demonstrates the importance of situating learning in a meaningful problem (Cognition and Technology Group at Vanderbilt, 1994). The jigsaw model of distributed expertise used in the "Facilitating Communities of Learners" model supports the social construction of knowledge (Brown et al., 1993) and develops both domain-specific knowledge and higher order thinking skills. The Computer Supported International Learning Environment (CSILE) project also successfully supports a collaborative knowledge-building community by using networked computers to help scaffold the students' critical-thinking skills (Scardamalia & Bereiter, 1993/1994).

PBL shares many features with these exemplary programs and adds unique strengths of its own. Many constructivist approaches often emphasize knowledge building for its own sake. Although many educators value this noble aim, students are often more motivated by pragmatic goals, what we call knowledge building for action (Guzdial, Turns, Rappin, & Carlson, 1995; Hmelo & Guzdial, 1996). One of the strengths of PBL is that it situates learning in concrete problems. The PBL tutorial groups foster use of distributed expertise. Finally, PBL can orchestrate coverage of an entire curriculum.

Problem-Based Learning for Gifted Students

PBL affords many learning opportunities that are particularly appropriate for gifted students, as is seen by considering several well-known characteristics of gifted students. In particular, gifted students are

1. better at acquiring and using knowledge in broader and deeper ways than their nongifted peers (Feldman, 1993; Sternberg, 1994);
2. likely to use more sophisticated strategies than those used by others their age (Zimmerman & Martinez-Pons, 1990);
3. better at regulating and evaluating their own cognitive activity (Bouffard-Bouchard, Parent, & Larivée, 1993; Zimmerman & Martinez-Pons, 1990);
4. better at transferring previously learned strategies (Borkowski & Peck, 1986; Jackson & Butterfield, 1986);
5. better able to deal with novelty (Sternberg, 1994); and

6. have a more functional and adaptive motivational orientation toward school tasks than their nongifted peers, including greater perceived control over their success and failures (Chan, 1996).

Although some may argue that the open-ended nature of the PBL process makes PBL a less efficient way to learn, it is precisely this quality that commends it for teaching the gifted. Because gifted students are more motivated, reflective, and strategic learners, PBL provides them with a rich context in which to capitalize on these strengths while constructing knowledge. For example, the novel real-world problem contexts, and the social settings in which they are embedded, are highly suited to gifted students—and even to students who have the abilities to excel but who might not be identified as gifted in traditional classroom settings (Sternberg, Ferrari, Clinkenbeard, & Grigorenko, 1996). Indeed, traditional, didactic education may limit the natural tendency of gifted children to be reflective, self-directed learners.

The Tutorial Process in Problem-Based Learning

Problem-based curricula provide students with guided experience in solving complex, real-world problems. PBL was designed with several important goals (Barrows & Kelson, 1995). It is designed to help students:

1. construct an extensive and flexible knowledge base;
2. develop effective problem-solving skills;
3. develop self-directed, lifelong learning skills;
4. become effective collaborators; and
5. become intrinsically motivated to learn.

Research is converging to demonstrate that some of these goals have been successfully met. Students in problem-based curricula are more likely to use their knowledge during problem solving and to transfer higher order thinking to new situations (DeGrave, Boshuizen, & Schmidt, 1996; Gallagher et al., 1992; Hmelo, 1995; Hmelo & Coté, 1996). Significantly, students who learned in an experimental PBL classroom learned at least as much social-studies (Gallagher & Stepien, 1996) and life-science (Hmelo, Holton, & Gertzman, 1997) content as those in a traditional classroom. The following sections of this paper describe the PBL tutorial process and highlight its key components, including the nature of the problem, facilitation, collaboration, and reflection. The tutorial groups

Table 1

The PBL Process

STARTING A NEW GROUP

1. Introductions
2. Climate setting and introduction to PBL roles (including facilitator)

STARTING A NEW PROBLEM

1. Setting learning objectives
2. Presenting the problem
3. Bringing the problem home
4. Assign tasks (Scribe at the board)
5. Use whiteboards:

FACTS	IDEAS (Hypotheses)	LEARNING ISSUES	ACTION PLAN
A growing synthesis of information obtained through inquiry that is relevant to the hypotheses generated.	Students' conjectures regarding the problem. These may involve causation, effects, possible resolutions, etc.	Students' list of what they need to know or understand in order to complete the problem.	Things that need to be accomplished in order to complete the problem.

6. Reasoning through the problem

   Continue re-representing, analyzing, and synthesizing ideas on the whiteboards.

FACTS	IDEAS (Hypotheses)	LEARNING ISSUES	ACTION PLAN
Analyze, Synthesize and resynthesize	Expand/Focus	Identify/Justify	Formulate plan

7. Learning issue shaping/assignment
8. Resource identification
9. Schedule follow-up and deadlines

PROBLEM FOLLOW-UP

1. Discuss resources used and their critique
2. Reassess the problem

   Apply what has been learned, revise hypothesis list

FACTS	IDEAS (Hypotheses)	LEARNING ISSUES	ACTION PLAN
Apply new knowledge and resynthesize	Revise	Identify new issues, if necessary	Redesign decisions

PERFORMANCE PRESENTATION

Table 1

(continued)

POSTPROBLEM REFLECTION
1. Knowledge abstraction and summary (what has been learned; may take the forms of diagrams, lists, etc.)
2. Self-evaluation followed by comments from the group and the facilitator) regarding: • reasoning through the problem • self-directed learning • participating in the group

Note. Adapted by permission of H. Barrows, Southern Illinois University School of Medicine.

provide much of the stimulus for student learning so understanding the nature of the tutorial process is critical to implementing PBL.

The PBL Tutorial Process

The PBL tutorial consists of several phases: starting a new group, starting a problem, problem follow-up, performance presentation, and postproblem reflection (Barrows, 1988). This sequence and some reminders for facilitators are shown in Table 1.

Starting a New Group. Before beginning to grapple with a problem as a group, students must get to know each other, establish ground rules, and establish a comfortable climate for collaborative learning. Meeting in a small group for the first time, students need to establish their individual identities. In the PBL tutorial, this occurs as each student, and the facilitator, gives a brief self-description. Not only does this allow students to establish their individual identities, it also helps students (and the facilitator) understand what expertise might potentially be distributed in their group. The other important function of this preproblem-solving phase is to establish a nonjudgmental climate in which it is important and, indeed, valued for the students (and facilitator) to recognize and articulate what they do not know (Barrows, 1988).

Starting a New Problem. Starting a problem in a PBL session begins by presenting a group of students with minimal information about a complex problem. The problem presentation should approximate how it would appear in the real world and engage the students. This helps the students relate to the problem context by having them consider who is affected by the problem or how they might solve it. In the lung problem, for example, students read newspaper articles about famous personalities and children with breathing problems.

Students also need to agree on who will take on the role of scribe. The chosen scribe records the groups' problem solving on whiteboards that list the *Facts* of the problem, students' *Ideas* or hypotheses, the *Learning Issues* they identify, and the *Actions* they plan to take (see below for a discussion of how the whiteboards are used in PBL). Early in the problem-solving process, the students and facilitator jointly agree on their objectives for the problem. The facilitator might ask the students, "What do you want to learn from this problem?" This question helps to explicate the groups' learning goals and helps all the group members work toward a set of shared objectives. These objectives can also help the facilitator to monitor the groups' progress and remind them when they are getting off course, or alternatively, to ask if they need to revise their goals (Barrows, 1988). Students may question the facilitator to obtain additional problem information or may gather facts by doing experiments or other research (Gallagher, Sher, Stepien, & Workman, 1995). For example, when middle school children were given the problem of trying to build artificial lungs, they did several experiments to determine how much air the lungs have to exchange (Hmelo et al., 1997). At several points in the case, students paused to reflect on the data collected so far, generated questions about those data, and hypothesized about the problem and possible solutions. In addition, the facilitator uses metacognitive questions to encourage reflective thinking by asking students to explain why they consider a particular solution to be good or why they need a particular piece of information about the problem.

As the students work on the problem, they identify concepts they do not sufficiently understand and so need to learn more about in order to solve the problem (the "learning issues"). Early in the PBL process, the facilitator may question students to help them realize what they don't understand. For example, they may ask puzzled students whether or not a particular issue should be added to the growing list of learning issues on the whiteboard. As students become more experienced with the PBL method and take on more of the responsibility for identifying learning issues, the facilitator is able to fade this scaffolding. Once the group has developed its understanding of the problem to the point that further progress is impeded by its lack of knowledge, the students divide up and independently research the learning issues they have identified (Barrows & Kelson, 1995).

Problem Follow-Up. In the problem follow-up phase, the students reconvene to share what they have learned, reconsider their hypotheses, generate new hypotheses in light of their new learning, or a combination of the three (see Table 1). This further analysis, and accompanying ideas about solutions, allows students to apply their newly acquired knowledge to the problem. Students share what they have learned with the group as they coconstruct their solution to the problem. It is important for students to evaluate their own information and that of others in their group. In the traditional classroom, information is often accepted at face value. In the PBL tutorial, the students discuss how they acquired their information and critique their resources, an important means of helping them become self-directed learners (Hmelo & Coté, 1996). Developing self-directed learning skills in response to problems is critical for the real-world situations that students face outside school (SCANS, 1991).

Problem Presentation. The emphasis in PBL is not just on having students solve the problem, it is on having them understand the cause of the problem. The problem statement includes both students' role and the product or performance that they are expected to produce. This helps provide students with a finite goal and with standards they must meet to consider the problem done. Indeed, the end product should have a real relationship to the problem under consideration. For example, students might produce a prototype model, as did students in the artificial lung problem, or they might report to a city council on zoning recommendations for an environmentally sensitive area.

Students demonstrate their understanding as they report on their conclusions in a variety of formats. Students spontaneously use a variety of different tools and skills to communicate their findings, including mathematical analyses, graphs and charts, oral presentations, and dramatic performances. Juxtaposing information in different formats helps students learn communication and interpretive skills also essential to success in the workplace (SCANS, 1991).

Postproblem Reflection. During postproblem reflection, students deliberately reflect on the problem in order to abstract the lessons learned. They consider the connections between the current problem and previous problems, considering how this problem is similar to and different from other problems (Barrows & Kelson, 1995). This reflection allows them to make generalizations and to understand when this new knowledge can be applied (Salomon & Perkins, 1989). As the students evaluate their own performance and that of their peers, they reflect on the effectiveness of their self-directed learning and collaborative problem solving. Such assessment is important for developing higher order thinking skills (Resnick, 1987).

As mentioned earlier, students use whiteboards to help scaffold and record their problem solving, with the scribe recording the group's deliberations (Figure 1). The whiteboard is divided into four columns to help the students record where they have been and where they are going in the PBL process. These four columns provide a scaffolding by helping communicate the problem-solving process in PBL (Hmelo & Guzdial, 1996).

Students use the whiteboard as a focus for negotiation of the problem and as a place to coconstruct knowledge. Figure 1 shows some of the entries made by a middle school group working on the artificial lung problem. The *Facts* column contains information that the students gathered from their research and experimentation. The *Ideas* column is used to keep track of their evolving hypotheses about solutions, such as the relationship between real and artificial lungs. The students place questions for further study into the *Learning Issues* column, while they use the *Action Plan* column to keep track of plans for resolving the problem. As the students work through their ideas and clarify issues, new learning issues may replace old ones, and information gleaned through research may be

Facts	Ideas	Learning Issues	Action Plan
Diaphragm is primary muscle for respiration	Will the artificial lung be like the real lung	How does CO_2 get out of the body	Collect materials that are elastic, spongy, light, absorbent
Diaphragm goes up, causes difference in pressure in lungs	Will we need to build different sizes for different ages	How much O_2 does body need	Dissect a mammal
		How will we measure that the body gets enough air	
Adult lungs holds 3 liters air	Need to make sure the body gets all the air it needs		

Figure 1. The PBL whiteboards.

added to the *Facts* column. In this way, the whiteboards provide an external memory aid in an iterative cycle of problem definition, information gathering, and solution synthesis (Gallagher et. al. 1995; Hmelo & Guzdial, 1996; Hmelo, Narayanan, Hübscher, Newstetter, & Kolodner, 1996). This simple device is a powerful tool for supporting the learning process, one that the facilitator must initially model to help students understand how to best use it.

The Role of the Problem

Experience with PBL and cognitive research has made important strides in identifying the characteristics of a good problem (Barrows & Kelson, 1995; Gallagher et al., 1992; Kolodner et al., 1996). In order to learn the thinking skills described earlier, PBL problems need to be complex, ill structured, and open ended. It is important that the problems be realistic and resonate with the students' experiences. They should be complex enough to have many interrelated parts, each important for a good solution. They should also motivate students and encourage them to go out and learn. Finally, a good problem affords feedback that allows students to evaluate the effectiveness of their knowledge, reasoning, and learning strategies and should promote conjecture and argumentation. As students generate hypotheses and defend them to others in their group, they publicly articulate their current state of understanding. This articulation enhances the knowledge construction process and sets the stage for future learning (Koschmann, Myers, Feltovich, & Barrows, 1994). In order to construct flexible knowledge, the problems in a PBL curriculum are also chosen such that concepts are revisited in a number of problems across the entire curriculum (Koschmann et al., 1994).

The Role of the Facilitator

The terms teacher, facilitator, and coach all refer to an individual trained to help students learn through PBL. The facilitator's role includes moving the group through the various stages of PBL, monitoring the group process to assure that all students are involved, encouraging students to externalize their own thinking, and commenting on that of others (Koschmann et al., 1994). By directing appropriate questions to individuals, the PBL facilitator acts as a metacognitive coach who guides the development of higher order thinking skills by encouraging students to justify their thinking and to externalize self-reflection. The coach's role is to help students understand what questions they need to ask during problem definition, fact finding, self-directed learning, and problem solution (Gallagher et al., 1995). This is done through metacognitive questions, such as, "What do you still need to find out?" rather than cognitive questions, such as, "How many chambers does the heart have?" In general, cognitive questions address domain-specific knowledge and procedures needed to solve the problem; metacognitive questions are domain general and refer to planning, monitoring, controlling, and evaluating the problem-solving process. The contrast between cognitive and metacognitive questions is illustrated in Table 2. The facilitator plays an important role in modeling the thinking skills needed to self-assess reasoning and understanding. Although the facilitator fades some of the scaffolding as the group gains experience with the PBL process, he or she still actively monitors the group and makes moment-to-moment decisions about how best to facilitate the PBL process.

Table 2

Examples of Cognitive and Metacognitive Questions

Cognitive Questions	Metacognitive Questions
What are the causes of lung problems?	So, what kinds of questions should we be asking at this point?
What is the role of the ribs in breathing? Do we need to design ribs in our artificial lung?	How do you know that? How could you find out?
	Does everyone in the group agree?

Collaborative Learning in PBL

One of the key features of PBL is small-group collaborative problem solving. A benefit of this structure is that it distributes the cognitive load among the members of the group and takes advantage of distributed expertise that allows the group as a whole to tackle problems that might be too difficult for each student individually (Pea, 1993; Salomon, 1993). This notion of distributed expertise is particularly relevant in PBL because, as the students divide the learning issues, they become "experts" in particular topics. Some students also excel at particular metacognitive skills, like question asking or evaluating the coherence of various solutions being considered by the group. Small-group discussions and argumentation that encourage individuals to coordinate different points of view can enhance reasoning and higher order thinking skills as well as promote shared knowledge construction (Blumenfeld, Marx, Soloway, & Krajcik, 1996; Brown, 1995; Vye, Goldman, Voss, Hmelo, & Williams, in press).

Reflection in PBL

One potential danger of learning in highly situated problem-solving contexts is that knowledge may become inert or context bound (Williams, Bransford, Vye, Goldman & Carlson, 1993). To avoid this, it is important that learners reflect on their learning and use concepts and thinking skills in a variety of contexts (Salomon & Perkins, 1989; Spiro, Coulsen, Feltovich, & Anderson, 1988). Reflection is important in helping students to (a) relate their new knowledge to their prior understanding, (b) abstract conceptual knowledge in a mindful way, (c) understand how specific strategies might be reapplied in novel tasks, and (d) understand the thinking and learning strategies they have used. PBL incorporates reflection throughout the tutorial process as well as upon completing a problem. By making inferences that tie general concepts and skills to the specifics of the current problem, students construct a more coherent understanding of the issues involved (Chi, Bassok, Lewis, Reimann, & Glaser, 1989). The reflection process in PBL is designed to help students exercise their higher order thinking skills as they make these inferences and identify any gaps in their thinking. This mindful stance toward learning is essential for efficient transfer of knowledge and strategies (Ferrari, 1996).

PBL as an Apprenticeship in Thinking

In a cognitive apprenticeship model, knowledge is constructed as learners work on real-world problems (Collins et al., 1989). With its emphasis on learning through problem solving, PBL exemplifies the cognitive apprenticeship model by making key aspects of expertise visible. The facilitator is an expert learner who is able to model good strategies for learning and thinking about the problem-solving process rather than being an expert in the content itself. Through the guidance of the facilitator, students externalize the questions that they should be asking themselves. For example, as students propose solutions to problems, the facilitator encourages them to explain and justify their thinking. These questions help model the use of hypothetical-deductive reasoning by encouraging learners to tie their inquiry to their hypotheses. Finally, the PBL tutorial sessions provide a model of the self-directed learning cycle (Figure 2). Facilitators fade their scaffolding as students become more experienced with PBL until finally the facilitators' metacognitive role is appropriated by the learners. The collaborative groups allow students to compare their theories and strategies with those of other students. Moreover, the facilitator-guided reflection helps prepare the students for transfer as they consider how what they learned and the strategies they used in working on the problem might be applicable in the future.

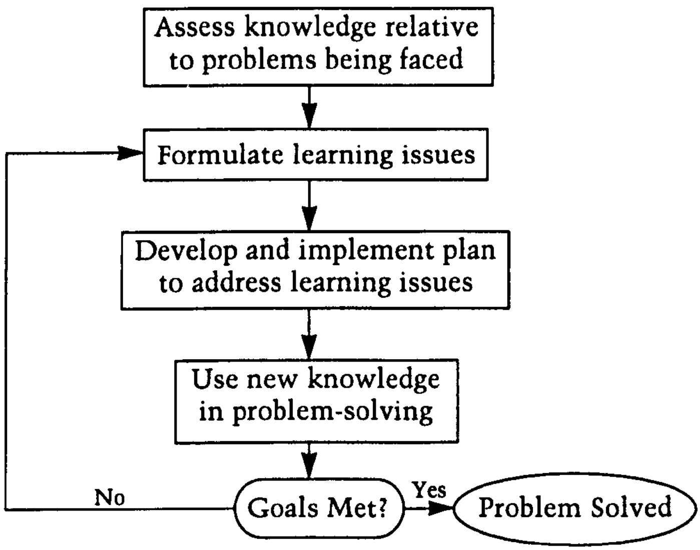

Figure 2. The self-directed learning cycle.

Starting PBL: Challenges for Teachers

Facilitators new to the PBL classroom can find themselves overwhelmed with new practices to which they must attend. Initial attempts at the facilitator role may be awkward as the teacher tries to juggle a new way of teaching against pressures to "cover the curriculum" (S. A. Gallagher, January, 1997, personal communication; Gertzman & Kolodner, 1996; Hmelo et al., 1997). When we asked one new facilitator, Mr. R., how he felt about his first experience with PBL, he expressed some awkwardness that was mixed with excitement over the students' reaction:

> Well, first I liked—I was very impressed with the end result. I was impressed with the level of my children's participation, their enthusiasm, as well as their open-mindedness to something beyond the traditional didactic method of teaching and learning. At first I felt as if it was a little artificial for me, because of the newness of the instructional method. . . . Once you take the artificialness away from it and let it become more a part of you and you are comfortable with it and with the materials, then it becomes much more natural; and a lot more learning is the end result.

A difficult issue for many new facilitators is the switch in emphasis from cognitive questioning to metacognitive questioning. Gertzman and Kolodner (1996) identified several strategies that one new teacher used, including the following.

1. *Jump starting:* questioning students about how they are going to get started or prompting them to consider the nature of the problem on which they are working.
2. *Check-ups:* often used to get students to think about how their current activities relate to their goals.
3. *Spotlighting:* occurs when the teacher focuses on a previously unremarked aspect of some new information, such as the source of a particular document.
4. *Stepping back:* structures students' problem solving; as the students begin to work on a problem, and during their problem solving, the teacher asks them about their problem-solving goals and subgoals.
5. *Dropping hints:* involves the teacher's attempts to get the students moving forward when they reach an impasse for lack of correct information.

The first four of these strategies are focused on process and provide metacognitive scaffolding. The last strategy is content focused. It is often used by beginning facilitators when they are worried that the students will not cover the curriculum content adequately or when the students appear to reach an impasse due to lack of relevant information (Gertzman & Kolodner, 1996; Hmelo et al., 1997).

This overemphasis on content may occur for several reasons. First, inexperienced facilitators may lack confidence that students will make progress through self-directed learning. Second, children may not yet have the cognitive tools required to ask the right questions, and teachers may need to model this for them (S. A. Gallagher, January, 1997, personal communication). In medical school, facilitators can assume that students have a well-developed knowledge base; but this is not necessarily true of the K–12 population in which students have a wide range of skills, prior knowledge, goals, and interests. Dods (1997) intersperses lecture with PBL to deal with this problem.

In trying to facilitate discussion at a metacognitive level, teachers new to PBL often forget to use the whiteboards effectively. New facilitators commonly start out well and have the students write down many facts, ideas, learning issues, and action plan items but then forget to return to the boards. The teacher can ask the students how a particular idea is related to the entries in the facts column or encourage discussion as she or he asks students if they wish to reconsider their ideas. By pointing out ideas that have been forgotten, the teacher can often use the students' own ideas to get them back on track.

Students who are learning curriculum content via PBL may take longer than do those in traditional classrooms, but the tradeoff is that students learn conceptual knowledge more deeply along with important metacognitive skills needed for lifelong learning. As time pressure increases, postproblem reflection is often abandoned. Not doing postproblem reflection is unfortunate because it provides an opportunity for students to consolidate and abstract what they have learned (and for the teacher to assess the students' understanding). Because PBL problems often cover more than just a single subject, it may be possible, for example, to integrate science and math instruction when both are covered and, thus, ease some of the time pressure. Time for reflection should be built in so that students can take full advantage of the PBL process.

Adapting PBL from medical school to lower levels of education provides many challenges for the teacher. New facilitators may need to be trained in the PBL process and receive feedback and support as they begin to implement PBL. The teacher struggles with the delicate balance between allowing unrestrained exploration and providing guided discovery. Teachers need support during their initial experience; they need mentors and colleagues to talk with for clarification and reassurance as well as for assistance with planning and implementing PBL units (Gertzman & Kolodner, 1996). To this end, it is useful for the teacher to first attend a PBL workshop to learn facilitation skills (Barrows & Kelson, 1995). The experience of facilitating the PBL process also provides feedback that can help teachers tune their facilitation skills. Workshops, mentoring, and collegial discussions help provide a supportive environment for teachers to deal with the challenges and opportunities that PBL provides.

Conclusion

The problem-based learning process was designed to cultivate higher order thinking skills and a flexible knowledge base. Working on complex, real-world problems helps learners construct more flexible ways of knowing and more productive ways of thinking that allow the learners to understand how and when knowledge can be applied. Understanding the nature of the tutorial process, including the role of the problem, collaboration among peers, and the importance of student reflection, is necessary to successfully implement PBL. As we have illustrated, reflection is integral to the PBL process and helps students prepare for transfer (Salomon & Perkins, 1989). Students revisit concepts and apply thinking skills in a variety of interrelated problems and from multiple perspectives that enhance deep learning (Spiro et al., 1988). Equally important, PBL takes particular advantage of gifted students' strengths at finding structure in a seemingly chaotic world.

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