Building a Better PBL Problem: Lessons Learned from The PBL Project for Teachers

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Introduction

Consider the following hypothetical example of a teacher trying a new approach to teaching science:

> *A high school biology teacher attempted a different approach to teaching a lesson about adaptations found in desert plants. She chose to teach the concepts by presenting a PBL lesson she found on a web site. Her students seemed bored, and she had difficulty getting her students to talk about the problem that served as the center point of the activity. As the activity progressed, her students were able to list some traits commonly associated with cacti, but the teacher did not see any different level of understanding than in past years when she gave lecture notes and a worksheet.*

Frustrations with PBL lessons resulting from disappointing outcomes may discourage teachers from trying to implement problem-based learning. Rather than assuming that problem-based learning is impractical, perhaps the problem in the case described above may be a poorly designed problem or a lack of experience in implementing PBL on the part of both the teacher and the students. Abandoning PBL as a teaching strategy may not be the best solution. According to the old adage, we try to build a better mousetrap. In this article, we offer suggestions for building a better PBL problem based on lessons we have learned as part of *The PBL Project for Teachers.*

Problem-based learning (PBL) is a teaching strategy that helps learners construct content knowledge by providing an authentic problem and engaging learners in finding and analyzing information. First used in the field of medical education (Barrows & Tamblyn, 1980), PBL's emphasis on critical thinking addresses many of the inquiry skills found in the National Science Education Standards (National Research Council, 1996). During a PBL activity, students are engaged in asking questions, collecting and analyzing information from multiple sources, hypothesizing, predicting, summarizing findings, and using evidence to justify claims. PBL activities can be helpful in introducing a new topic, building conceptual understandings, and as transfer tasks that allow students to apply their knowledge to new situations.

Despite being an appropriate and versatile strategy for teaching inquiry-oriented science, most teachers have little experience designing and implementing PBL lessons (McDonald & LaLopa, 2006). Teachers often report that they struggle to "find PBL activities." There are a few resources where teachers can download lessons built around a PBL framework, but often these resources do not meet the teacher's individual needs.

The PBL Project for Teachers is a professional development program for K-12 teachers that uses PBL as a framework to guide teachers' learning of science content and pedagogical strategies. The primary goal of the project is to help teachers analyze and improve their teaching, thereby deepening students' understanding of science. Many of the participants in the project, however, have begun to use problem-based learning as a structure for designing lessons for their own students. At the request of participants, project leaders conduct seminars on teaching strategies and PBL lesson design using a backward planning process. During unit development, participants first identify learning goals and objectives, then describe how they will recognize when students have achieved the goals. From this information, teachers can develop assessment strategies and a sequence of activities that will help students learn the desired concepts. Examples of the process of planning PBL lessons are included in other articles in this section of the *MSTA Journal*.

Structuring PBL Lessons

Problem-based learning is generally defined as an approach that helps students "learn to learn" through analysis and resolution of open-ended, ill-structured real-world problems. These problems provide a relevant context and a need to learn concepts in order to solve the problem. Figure 1 summaries research conducted as part of *The PBL Project for Teachers* about the design of effective problems (Oslund, Low, Mikeska, Weizman, Lundeberg, Koehler, & Eberhardt, 2006) suggesting that they should reflect authentic situations that are both relevant and interesting to students. The problems should have more than one viable hypothesis, and should be challenging enough to naturally lead to clear roles for students as they work collaboratively to find a solution. The literature on problem-based learning often refers to these problems as "dilemmas." For the purpose of our articles, we use the term "problem" to refer to scenarios that lead learners to a specific concept, such as the impact of an invasive species on an ecosystem.

Important Elements of a PBL Problem

Research on the design of effective PBL lessons suggests that the following elements are essential components of effective PBL problems.

1. Appropriate for Curriculum
2. Allow for Inquiry-oriented Exploration
3. Authentic & Relevant
4. Engaging
5. Open-Ended
6. Appropriately Challenging
7. Availability of Information and Resources

Figure 1: Elements of effective PBL problems. (adapted from Oslund, et al, 2006)

When we talk about a "dilemma," we are describing a complex issue with multiple correct answers, each of which is equally viable. Dilemmas are a more appropriate term for PBL analysis of teaching science, because the term implies an ongoing issue that the teacher struggles to test and revise. This article will describe the kinds of scenarios we find are most effective when used as PBL problems. In a later article in this special section, we will describe how teachers develop their own dilemmas in a process very different from the selection of PBL problems.

Appropriate for Curriculum

One of the first considerations in developing a PBL problem (like any other plans for instruction) should be the learning goals. In the PBL Project, we advocate a backward planning approach to unit development, beginning with selection of the concepts to be addressed by the unit. This is an appropriate planning strategy for planning a science lesson for children or adult learners, and is just as appropriate when we plan to use PBL problems that address science teaching strategies in professional development.

All of us recognize the current emphasis on standards in science education. When planning a science problem, educators should consider not only the "big ideas" of the lesson, but should also identify the grade level expectations and standards. This starting point will ensure that the teacher is not devoting time and energy on topics that do not help cover important content.

As reflected in a template that we have created for developing problems (PBL Project for Teachers, 2007), we also found it helpful to consider learners prior ideas, either by assessing what the learners know or by finding out what common misconceptions people often have about the science concepts we identified. These misconceptions and prior ideas can help us select activities that will address the specific learning needs of our group of students.

Allow for Inquiry-oriented Exploration

Problem-based learning is an inquiry-oriented strategy. There are many different definitions of "inquiry," though, so we need to think about what aspects of inquiry are addressed in PBL. PBL is not the only form of inquiry, and it is certainly not "open" inquiry (Colburn, 2004) in which learners direct their own independent research. Learners may engage in a PBL problem only through a search of science literature, or they might collect data in an authentic science experiment over a period of time. But in any effective PBL lesson, learners practice at least some of the process skills identified as "inquiry" in the National Science Education Standards (NRC, 1996). Among these inquiry skills include:

- asking questions
- thinking critically about relationships between evidence and explanations,
- constructing and analyzing alternative explanations,
- communicating scientific arguments.

Authentic and Relevant

One of the strengths of problem-based learning is that students gain practice in applying knowledge to real-world situations. However, this requires that the scenar-

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ios we use as PBL problems represent authentic problems. It is also important that the real-world problems we include in PBL problems are familiar enough to the learner to be perceived as relevant and important to the learner. Developing an effective PBL problem therefore requires some understanding of the specific group of learners.

We also found the same criteria of authenticity and relevance helpful in developing a transfer task – an assessment activity that gives the learners a chance to apply the science content they have learned to a different problem that illustrates the same concepts.

Engaging

Understanding the audience is even more important in constructing PBL problems that are engaging! The problem must be interesting to the learners. This can be difficult to gauge because, as adults, we sometimes have different perspectives about what is "interesting." As teachers, we have probably experienced a lesson we thought would grab students' attention, only to find that the idea flops from a lack of interest. What we might get very excited about may lead children or adolescents to ask "So what?"

Two approaches we have utilized in *The PBL Project for Teachers* to ensure that our problems were authentic, relevant, and engaging can also be applied to planning for science PBL problems for any group of learners. The first is to find ideas from current events. The newspaper, magazine articles, television news programs, and even TV series and movies can sometimes lead us to topics that can be explained by science concepts we teach in our courses, and have the "wow" factors that will hold our students' interest.

Another helpful strategy is to use student-generated questions and ideas as the starting point from which we build problems. One of the participants in *The PBL Project for Teachers* has done this by having students write some of the questions they ask in class on a slip of paper. The papers then go on a bulletin board, and the teacher can select from the questions to plan future science lessons. When planning the problems we implement for our professional development program, we begin by asking teachers to the identify science content topics they need to understand more thoroughly, and then find relevant topics that lend themselves to the PBL approach. In both examples, the learners generate the topics, and often the scenario, increasing the chances that the problem will be engaging to others.

Open-Ended

Real-world problems are seldom neat and easy to answer. An effective PBL problem usually is open-ended enough to allow for multiple, viable hypotheses or answers. When students in the same class develop diverging sets of recommendations, the opportunity for discussion and the need to justify their answers based on evidence leads to a deep understanding of the concepts. More importantly, through their defense of hypotheses using evidence, the students learn about the process of defending their ideas that scientists must negotiate in order to confirm their ideas with others.

Appropriately Challenging

In a recent article in MSTA Journal, McDonald and LaLopa (2006) mention that PBL problems often do not offer enough challenge to push students thinking, and our research confirms the importance of making problems appropriately challenging. Teachers reported lower satisfaction with problems that could be answered with little or no need to search for answers or explore phenomena. When learners already possess the prior knowledge they need to come to a quick answer, a dilemma cannot contribute to either content learning or the development of critical thinking skills. If the problems posed to learners are more complex or require more in-depth understanding of scientific principles, learners are forced to work as a team to find, interpret and apply information. This process contributes to the construction of new ideas and the ability to critically think about new situations. If we think of the need for authentic, relevant and engaging topics as a way to spark students' need to know, developing challenging problems is the necessary to push learners to stretch their understandings of science to new boundaries. On the other hand, if learners have no prior knowledge that gives them a place to start attacking the problem, they are often frustrated and give up.

Availability of Information and Resources

When planners of the PBL Project brainstormed ideas for content problems and teaching dilemmas, we sometimes came up with ideas that we agreed would be interesting, challenging, and relevant. However, if the resources that might help learners answer the questions are not readily available to them, not being able to access (or understand) them is a source of frustration. The task needs to be challenging, but accessing the required information should not be so difficult that students give up. This is especially true for students who are new to problem-based learning and similar contextualized problem-solving strategies. When learners are still learning to think critically and solve problems, teachers may need to provide additional help in finding helpful resources. Participants in *The PBL Project for Teachers* have found it necessary to provide Internet or text resources to student groups to streamline the process of doing research. As students gain experience and learn to search for information independently, we can withdraw some of the support. The articles that follow illustrate some of the approaches to student information searches teachers in the project have implemented.

Implementing the PBL Activity

Another important consideration when planning to implement a PBL science lesson involves the roles of both teacher and learners in the lesson. As McDonald and LaLopa pointed out in their 2006 article, the teacher plays a very different part in a PBL activity than in other instructional strategies. The presentation of the lesson also follows a different pattern than most other types of lessons. In the articles that follow in this special section of the *MSTA Journal*, teachers who participated in the PBL Project share some examples of PBL lessons they created. These lessons provide practical examples of the lesson structure described in the following section.

The Scenario

PBL problems begin with a scenario, usually written as a story. The approach we have found most effective is to present the scenario in two parts. The first segment (we simply call it Page 1!) gives just enough information to pique student's interest in the problem. Page 1 includes a question that draws the learner's attention to the problem they will be analyzing, and gives just a small amount of background information. After reading the scenario, the group then discusses what they know, what they need to know, and hypotheses about solutions to the problem. In our experiences, if Page 1 has too much information, it limits the number of hypotheses the group will generate. Some participants have expressed frustration with the number of hypotheses students create in discussion of Page 1, but we find this an essential step in the learning that takes place in PBL. One of the skills students must exercise is the ability to identify testable and relevant hypotheses – a step that must take place before they begin searching for resources.

Page 2 of the activity provides more relevant information about the problem. This step gives the learners background information, helps clarify the problem, and often helps them eliminate some of the hypotheses they generated. Page 2 should include enough information to guide the group toward useful learning issues,

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Figure 2: The roles of teachers and learners in Aeffective PBL lessons.

Roles of teachers and learners in PBL Lessons

Teacher's Roles	Learners' Roles
• Co-Learner!	• Compile facts and known information about scenario.
• Present and clarify the challenge or the problem.	• Brainstorm possible solutions, prioritize the list.
• Guide learners in evaluation of evidence and information.	• Identify learning issues.
• Assist students in search for information, provide resources.	• Gather and evaluate info from multiple sources.
• Monitor and re-direct students - keeping students on task.	• Develop and discuss action plan, recommendations.
• Assessment of student performance.	• Present and defend group's plan or recommendations.

but not enough to give them "answers" to the problem. Once again, the group then discusses what new information they have and what they still need to know. They can also eliminate previous hypotheses or generate new ones, then prioritize the learning issues they wish to research.

Groups of learners then seek information from various sources. As mentioned earlier in this article, teachers may provide resources for the group, students might search the library or on-line resources, or the students might do a hands-on activity to collect data to be analyzed. Once this research step is completed, the group once convenes to discuss the information they found and how it relates to the problem. This step includes the creation of recommendations for answers to the problem, and can be done either in small groups or as a whole class.

Facilitating Learning in a PBL Dilemma

When selecting a topic and developing a problem for a PBL lesson, the teacher needs to plan for students to be the driving force behind formulating hypotheses, identifying the learning issues, interpreting information, and synthesizing new ideas. In order to help teachers recognize their roles and plan scenarios that maximize student participation, Figure 2 below offers a list of roles we have found teachers and learners enacting in effective PBL activities. These roles are also important in planning a PBL problem. The teacher should consider if the scenario presented allows students to engage in the process as described in Figure 2.

The elements of an effective PBL problem are applicable to a wide range of scenarios and groups of students. But the specific problems that will work with your students are very specific to the context. Relevant problems for a group of middle school students in an urban setting may be very different from those for a rural high school physic class. It is important that teachers develop PBL activities that are appropriate for each specific group of learners. When teachers plan to use PBL as a strategy for teaching science, we hope the information we have shared in this article can serve as a guide to make planning easier and more effective.

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