The PBL Project for Teachers: Using Problem-Based Learning to Guide K-12 Science Teachers' Professional Learning

By Tom J. McConnell - Research Associate, Division of Science & Mathematics Education, Michigan State University; Jan Eberhardt - Assistant Director, DSME, MSU; Joyce M. Parker - Assistant Professor, DSME, MSU; Jeannine C. Stanaway - Instructor, College of Education, MSU; Mary A. Lundeberg - Professor, Teacher Education, MSU; Matthew J. Koehler - Associate Professor, Ed. Psych. and Ed. Tech., MSU; Mark Urban-Lurain - Director of Instructional Technology Research and Development, DSME, MSU; and the staff of The PBL Project for Teachers

"I've been teaching for 30 years, and PBL has invigorated my approach to teaching. I look forward to teaching, and my students look forward to science." (Agnes Drzal, 6th grade teacher, Kinawa Middle School)

Professional development for science teachers is often designed to guide teachers in the use of specific teaching strategies, curriculum packages, science units, or school improvement initiatives. Too often, professional development offers a one-size-fits-all solution for teachers from all subjects or grade levels. When paired with the traditional one-shot workshops, it is little wonder that so many professional development programs fail to bring about changes in how teachers teach and students learn.

The Problem-Based Learning (PBL) Project for Teachers approaches K-12 science teacher professional development in a comprehensively different way. The focus of the PBL Project is to improve science teaching and learning. Teachers who enroll in the PBL Project learn about science content, develop age-appropriate standards-based units around the concepts they learn, and then study the effectiveness of their implementation of the units. Each phase of the professional development program is structured under a Problem-Based Learning framework to guide teachers' thinking and learning.

Problem-based learning (PBL) is a teaching strategy first developed in the medical education field (Barrows & Tamblyn, 1980) to help students develop both content knowledge and the clinical reasoning skills needed by medical professionals. PBL has since been adapted for teaching science (Allen, Duch, Groh, Watson, & White, 2003; Gordon, Rogers, Comfort, Gavula, & McGee, 2001), and has been shown to increase students' intrinsic motivation to become self-directed learners (Hmelo-Silver, 2004; Kelson, 2004). Because teachers are engaged in the same kind of clinical reasoning as doctors – diagnosing problems in learning content, and making multiple decisions about how to address those problems – we use a PBL framework to help teachers systematically think about their own practice.

In this article, we explain the Problem-Based Learning framework and provide an overview of *The PBL Project for Teachers*. The articles that follow in this special section of the MSTA Journal describe lessons we have learned about the design of effective PBL science problems and offer examples of PBL science lessons designed by participants in the PBL Project.

The PBL Process

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, or "dilemmas" (Torp & Sage, 2002). A more extensive explanation of the characteristics of an effective problem or dilemma is given in the final article in this special section.

After reading the scenario presented in the problem, groups of learners then work through a structured framework of analytical steps as they develop recommended actions to address the problems. These steps help the learners to explicitly state the information they have, identify questions that need further research, and propose hypothetical solutions, and analyze information they gather in order to develop a proposed resolution to the problem. Figure 1 provides a summary of the PBL process as used in the PBL Project's professional development activities. The objective of the framework is to provide the learners with experi-

The PBL Process

While there are some variations on the analytical process used in PBL activities, the PBL Project draws models from Dean (2001) and Torp and Sage (2002), and includes the following steps.

1. Read the Initial Problem (page 1)
2. Group Discussion
    a. What do we know about the scenario?
    b. What do we need to know?
    c. Hypotheses about the problem.
3. Read More Information about the Problem (page 2)
4. Group Discussion
    a. What do know now?
    b. What do we still need to know?
    c. Revised hypotheses
    d. Prioritize learning issues and assign research tasks
5. Research – internet, library, texts, or hands-on experiences
6. Group Processing of Research Findings
    a. Summarize results
    b. Revisit learning issues
    c. Revise hypotheses
    d. Propose and defend recommended actions
    e. Plans for further questions/research

Figure 1: Summary of the Process for Analyzing PBL Problems and Dilemmas

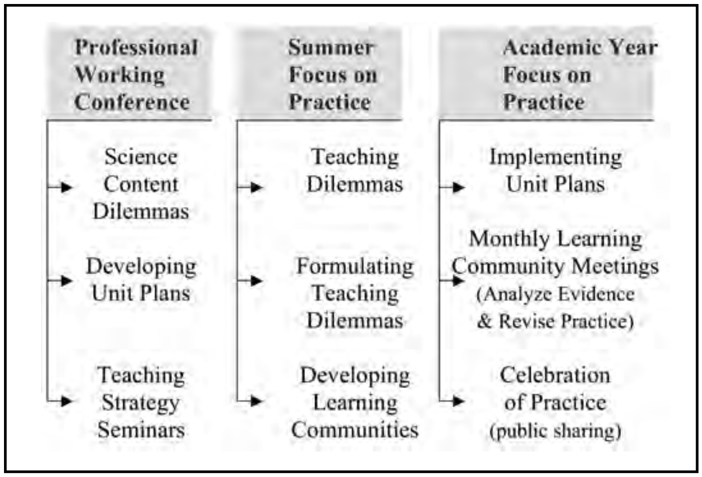

Figure 2: Overview of the PBL Project for Teachers

ences that illustrated content knowledge and practice in applying that knowledge in a contextual setting that is relevant and interesting. The steps shown in Figure 1 also contribute to the development of critical thinking skills called for by the National Science Standards (NRC, 1996).

Problem-based learning has been used as a strategy for teaching science content, but the PBL Project had utilized the same set of analytical steps to guide teachers' learning about curriculum and teaching strategies. This novel application of the PBL approach engages teachers in a systematic analysis and revision of curriculum, science unit plans, and teaching strategies. The following section describes the design of *The PBL Project for Teachers* to illustrate the overarching theme of problem-based learning as it is used to address both content learning and instructional decision-making.

Overview of the PBL Project for Teachers

To date, about 140 teachers in grades K-12 from across mid-Michigan have used the PBL learning framework described above to analyze problems or dilemmas relating to both science content and the science teaching as participants in *The PBL Project for Teachers*. The following overview of the professional development program will help illustrate how PBL helps teachers deepen their understanding of both content and pedagogy. The PBL Project involves three main components. Figure 2 shows the three components, with the main activities of each component. Participants have the option of enrolling in just the first component, or all three.

The first two components of the professional development take place in the summer, beginning with a 7-day Professional Working Conference. Planning for the Professional Working Conference begins when teachers select a first and second choice of science topics they wish to improve in their own teaching. Project staff then group participants in content "strands" and develop a series of PBL problems that relate to the topics identified by teachers. Examples of the content strands for the Summer 2007 workshops included Solid Earth, Astronomy, Force and Motion, Genetics, Ecology, Organisms, and Weather. During the first three days of the summer workshops, teachers then use the PBL framework to analyze science-related problems associated with their chosen topic.

The Professional Working Conference also includes four days of unit development. Teachers develop or revise unit plans for their own content strand topics by identifying the appropriate "big ideas" and standards for their students. They then plan assessments that will demonstrate student understanding, and develop a se-

continued on page 18

quence of lessons to help students learn these concepts. Teachers also use this time to participate in seminars to explore inquiry and application teaching strategies as they plan for their science units.

Participants who opt to enroll in all three portions of the project continue on to the second segment, the Summer Focus on Practice. This component consists of three days during which participants are positioned as teacher-researchers who actively analyze their teaching practice. To learn to use PBL as an analytical tool, groups of participants take part in teaching dilemmas that serve as practice cases for the groups to analyze. In this article, we use the term “dilemma” to describe the problems teachers choose to study because the word implies an on-going struggle to decide between more than one equally viable plan of action. The teaching dilemmas include background information on a grade-specific problem or issue that a teacher wants to resolve in her own classroom. A videotape of the teachers' science classroom is used to illustrate the teacher's dilemma. Participants then use the PBL framework to analyze the problem, form hypotheses for solutions, search for literature on the issue, and recommend strategies that address the dilemma. The experience is designed to model the process that participants use while researching their own teaching dilemmas during the following academic year with a learning community of their peers.

Participants then work with their learning community to identify a dilemma in their own teaching related to the unit they developed during the Professional Working Conference. The problems addressed in teachers' analysis of their practice are drawn from their classroom experiences. For instance, a participant may plan to use a new inquiry approach to teaching the concepts of velocity and acceleration. Her dilemma may test whether the new activities help students learn the concepts more thoroughly. Other teachers may be struggling to develop alternative assessments or portfolios that help them understand what students have learned. Like in the Professional Working Conference, the teachers select the topics that guide the learning.

Selecting a problem of teaching practice may seem simple, but because identifying a question is so important to the research process that follows, we have found that teachers develop teaching dilemmas that are easier to study when they are very deliberate and specific in the process of identifying the issue they wish to explore. Participants in *The PBL Project for Teachers* use one of four lenses - instructional decision-making, student interactions, content, and assessment – to focus their study on specific issues in their teaching. They then brainstorm several issues related to the unit they developed, as well as a list of possible interventions or strategies to deal with the issues. The teachers prioritize their lists and refine one or two questions that will guide their inquiry during the following school year. They then develop testable hypotheses that serve as a foundation for a data collection plan that will provide evidence about the impact of their selected intervention. Table 1 provides some examples of dilemmas and hypotheses developed by teachers in *The PBL Project for Teachers.*

Once teachers have selected a dilemma, they then create a plan for collecting evidence from their own classrooms, which may include test scores, samples of student work, and videotaped segments of science lessons, or could include other assessments such as observation checklists (Burke, 2005), teachers' written reflections. The participants also have an opportunity to practice using video camcorders and *iMovie* video editing software (Apple, 2006) to capture and organize the videotaped evidence of practice.

In the final segment of the professional development program, the Academic Year Focus on Practice, teachers implement the lesson and the research plan they developed in the summer. They collect evidence of student learning and record videotape of the lesson in which their teaching dilemmas are situated. With the help of analytical questions provided in materials developed as part of the project, teachers can then view the videotapes, look for evidence of changes in student achievement, behavior, or learning, and create a series of video clips that can be shared with their peers.

The learning communities developed during the summer meet once a month to analyze the evidence teachers collected during the teaching of their unit plans. Members of the group take turns presenting their dilemmas to the group, starting with the context and the lesson taught. The presenting teacher shares the evidence he or she collected, and the group uses the same PBL learning framework to analyze the situation and identify learning issues. Prior the next month's meeting, the participants gather relevant information from

Teacher*	Grade	Summary of Dilemma	Hypothesis
Debra	3	Students' misconceptions have caught me off guard at the end of units or teaching cycles. How can I identify and address misconceptions?	If more formative assessment is incorporated into the plants unit, then students will reveal their misconceptions as topics are discussed because evidence of misconceptions and missing knowledge will be available immediately.
Theresa	6	How can I get students to be complete in answering questions or solving problems without leading them to the "right" answer?	If I use an application activity cycle to teach students to utilize evidence, then they will give more complete answers because the process of explaining evidence has been modeled.
Julie	7	When doing a PBL or inquiry based experience with 7th graders, how does one structure the research experience so that they use their time as effectively as possible?	If students create a rubric about what is expected from their research time, then students will use their research time effectively and complete their research because they have ownership in the resulting learning.
Eric	9-12	How can I use formative assessment in ways that help my students understand science concepts?	If I utilize formative assessments regularly in a lesson/unit, then students will be able to explain concepts more accurately because they will receive feedback throughout the learning cycle of the lesson/unit instead of just at the end.

*Note: Teacher names are pseudonyms.

Table 1: Examples of teaching dilemmas generated by PBL Project participants.

library and Internet resources. The teacher-researchers then discuss their findings as they develop new strategies for dealing with this dilemma. The knowledge of teaching developed from this teacher research can then serve to guide planning of future science lessons.

The Focus on Practice ends with a Celebration of Practice, a chance for all the learning communities to share the results of their research. This opportunity to debrief with others recognizes the participants' contributions to a collective body of teacher knowledge and helps the participants solidify in their own minds how they have changed as teachers.

Impact of PBL Project for Teachers

The implementation of the PBL Project's professional development model has provided many opportunities to study the kinds of changes teachers undergo. Some of the evidence collected as part of this research suggests that the use of PBL as a tool for professional development can have important impacts on teacher knowledge.

Understanding Science Content and Curriculum

Participants in the project are gaining science content knowledge. Teachers often come to the project with a basic understanding of the science concepts they teach,

continued on page 20

especially the patterns that illustrate such topics as heredity, moon phases, and forces that affect motion of objects. However, some lack the depth of understanding needed to explain to students why these phenomena occur. For these teachers, the PBL Project's content problems have given them a chance to develop a deeper understanding of the subjects they teach.

"I honestly feel like our growth and our increased knowledge changes how much the kids get out of it. Because of what I was able to learn, I reorganized my succession unit, and I'm able to make so many more connections! And now in the MEAP review, my kids are remembering what they learned in my class." (Lee Ballor, 8th grade teacher, Chippewa Middle School)

Even teachers who have extensive education in their content area have gained from taking part in the application of ideas to real world problems, enlarging their repertoire of examples and explanations that enable them to teach science to their students.

We have also found that teachers have made important changes to their science curricula as a result of the work they completed during the PBL Project. On project evaluation questionnaires, many of the participants have reported that they focus more on the "big ideas" of science, and have trimmed parts of their curriculum that are not necessary to align with state and national standards. Others have explored new teaching strategies, including the development of problem-based lessons for their students and alternative approaches to assessment that help both teacher and students gauge learning.

PBL as a Tool for Professional Learning

One of the goals of *The PBL Project for Teachers* is to provide educators with a framework for analyzing their practice with the goal of improving science teaching. Another important impact of *The PBL Project for Teachers* is that participants are beginning to use PBL as a way to examine and revise their teaching. In assessing PBL's ability to give structure to teachers' inquiry, participants are reporting that they have begun to apply the PBL framework to analysis of teaching in other subjects as well. Linda is an elementary teacher at a small parochial school. Her experience exemplifies this kind of change in teachers' thinking. After participating in the project's first cohort, she reported, "Now I use PBL to re-examine not just my science lessons, but math as well! Thinking about my teaching in a PBL framework has become part of who I am as a teacher." In another example, Kristin, a middle school teacher in a rural school, shared her experiences in the PBL Project with others in her building. As a result, her building principal has encouraged the school's staff to use many of the features of PBL as a strategy for school improvement planning.

Implications for Science Teachers

Standards for science education (NRC, 1996) and staff development (NSDC, 2001) both emphasize the need for teacher "inquiry into teaching and learning" (NRC, 1996, chapter 4). This increasing emphasis on teacher research is reflected in the creation of "Teacher Researcher Day" at the National Science Teacher Association's annual conferences and in the growing body of literature on the role of teacher inquiry in professional learning (Roberts, Bove, & van Zee, 2007). We are using problem-based learning as a framework to help teachers structure inquiry about their own science teaching.

For science teachers, questions about which instructional strategy to use usually lead to choices between many options. Using PBL as an analytical framework helps teachers make evidence-based decisions based about effective science teaching strategies. The evidence about the efficacy of the intervention comes from student work, the teachers' observations and reflections, and from records of classroom events that might include videotaped lessons. The teacher's analysis of the evidence, conducted in collaboration with a group of peers, guides instructional decisions. The findings can then inform others about effective strategies for specific contexts.

PBL has the ability to develop science content knowledge in a contextually appropriate setting while simultaneously helping learners practice critical thinking skills. But PBL is more than just a strategy for teaching science. PBL also provides a framework that is useful for teachers as they reflect on and analyze their own practice in an on-going process of professional learning. The PBL framework can become an integral part of school improvement efforts while meeting the needs of teachers who face changes in curriculum and standards.

The articles that follow share examples from participating teachers of problem-based lessons they have developed for their own classroom and their use of the PBL framework to examine their own practice. The final article in this special section discusses lessons we have learned during the design and implementation of our professional development activities about designing PBL problems.

References

Allen, D. E., Duch, B. J., Groh, S. E., Watson, G. B., & White, H. B. (2003). Scaling up research-based education for undergraduates: problem-based learning. .Reinvigorating the Undergraduate Experience: Successful Models Supported by NSF's AIRE/RAIRE Program. Retrieved Sep. 1, 2004, from http://www.cur.org/publications/AIRE_RAIRE/printer/ delaware.asp.

Apple Computer, Inc. (2006). iMovie HD 6.0.3 [Computer software.] Cupertino, CA: Apple.

Barrows, H. S., & Tamblyn, R. M. (1980). Problem-based learning: An approach to medical education. New York: Springer.

Burke, K. (2005). How to assess authentic learning. Thousand Oaks, CA: Corwin Press.

Dean, C. D. (2001). They expect teachers to do that? Helping teachers explore and take ownership of their profession. In B. B. Levin, (Ed.), Energizing teacher education and professional development with problem-based learning. Alexandria, VA: Association for Supervision and Curriculum Development. pp. 8-23.

Gordon, P. R., Rogers, A. M., Comfort, M., Gavula, N., & McGee, B. P. (2001). A taste of problem-based learning increases achievement of urban minority middle-school students. Educational Horizons, 79(4), 171-175.

Hmelo-Silver, C. E. (2004). Problem-based learning: what and how do students learn. Educational Psychology Review, 16(3), 235-266.

Kelson, A. C. (2004). The power of problem oriented learning. Paper presented at the Problem-Based Learning Professional Development Project.

National Research Council [NRC]. (1996). National Science Education Standards. National Academy Press: Washington, D.C.

National Staff Development Council. (2001). Standards for staff development. Oxford, OH: National Staff Development Council.

Torp, L, & Sage, S. (2002). Problems as possibilities: Problem-based learning for K-16 education. Alexandria, VA: Association for Supervision and Curriculum Development.

Roberts, D., Bove, C, & van Zee, E. (Eds). (2007). Teacher research: Stories of learning and growing. Alexandria, VA: NSTA.

Contact Information:

*To learn more about **The PBL Project for Teachers**, including contact information for project staff, visit http://pbl.educ.msu.edu.*

First Author's Contact Information:

102 North Kedzie Lab
Michigan State University
East Lansing, MI 48824
tommac@msu.edu
Work: (517) 432-2152 Ext 114
Home: (517) 833-4847

Acknowledgements

- The authors wish to acknowledge *The PBL Project for Teachers*.
- A complete listing of project staff can be found at http://pbl.educ.msu.edu
- This material is based upon work supported in part by the National Science Foundation, under special project number ESI – 0353406 as part of the Teacher Professional Continuum program.
- Any opinion, finding, conclusions or recommendations expressed in this publication are those of the authors and do not necessarily reflect the views of any of the supporting institutions.