Preparing Science Teachers using a Problem-Based Learning Framework

Mary Lundeberg

Teacher Education

Matt Koehler

Educational Technology

Jan Eberhardt

Joyce Parker

Division of Mathematics and Science Education

Meilan Zhang

Tom McConnell

Ayelet Weizman

Teacher Education

Michigan State University

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Abstract

We view teachers as clinicians – individuals who must assess, diagnose, prescribe, and adjust their practice to reflect new research, knowledge, and experience. Recognizing the teacher as a clinician requires professional development (PD) opportunities that change to meet teachers' needs over the span of their career. Medicine – perhaps the most highly visible clinical professional discipline – has been successful in educating their professional clinicians using Problem-Based Learning (PBL). We have extended the medical approach to PBL by conceptualizing, designing, implementing, and researching its applicability to the professional development of teachers. Our efforts with inservice teachers focused on the design of a Problem-Based Learning curriculum through which participants deepened their pedagogical content knowledge and analyzed, revised, and improved their own instructional practice in science. With preservice teacher candidates and undergraduate level, we have incorporated problem-based learning into key subject matter and teacher preparation courses, and we are beginning to study the impact on preservice teachers' learning. In this paper, we will present both the model we have developed as well as some of the research we have conducted thus far.

PBL as a Tool for Developing Professional Knowledge

Problem-Based Learning (PBL) was originally designed for medical education, and much of the research that supports it comes from studies of its effectiveness in medical schools (Albanese & Mitchell, 1993; Barrows & Tamblyn, 1980; Dochy, Segers, Van den Bossche, & Gijbels, 2003). Albanese and Mitchell (1993) defined PBL as "an instructional method characterized by the use of patient problems as a context for students to learn problem-solving skills and acquire knowledge about the basic and clinical sciences" (p. 53). In medical schools, problems are presented as written case histories about patients (Barrows & Tamblyn, 1980). Students work through the problem by listing the facts of the case, hypotheses, and learning issues or questions, which they prioritize in terms of their importance to solving the problem. After that, students are released for a time to do self-directed learning around the issues they identified. They later reconvene to share what they have learned, agree on a diagnosis, and collaborate to make a decision regarding treatment.

While the majority of the literature on PBL has been conducted in medical schools, educators in other professional fields have begun to adapt PBL to their own contexts. PBL has been used in nursing (Newman, 2004; Newman et al., 2001), undergraduate science courses (Allen, Duch, Groh, Watson, & White, 2003), preparation of preservice teachers (Butler, 2003; Derry, Seymour, & Fassnacht, 2001), undergraduate economics courses (Capon & Kuhn, 2004), educational psychology (Chernobilsky, DaCosta, & Hmelo-Silver, 2004), and middle school science (Gordon, Rogers, Comfort, Gavula, & McGee, 2001).

In a recent meta-analysis of studies on PBL in medical schools, Dochy, Segers, Van den Bossche, & Gijbels (2003) found that, compared with students in traditional lecture-based courses, students in PBL courses gained slightly less knowledge but were better able to apply knowledge and higher order thinking skills. In another study, Capon and Kuhn (2004) compared learning outcomes on two concepts taught in an undergraduate economics course. Each of two groups of students learned one economics concept using PBL and the other using a traditional lecture and discussion method. They found that both groups of students could provide definitions for both concepts, but that each group could more fully explain the concept that they learned using PBL. These studies suggest that PBL has the potential to develop depth of understanding, rather than breadth.

The process of problem-based learning is intended to mirror the clinical reasoning process of professionals who have to make decisions without having complete information. One of the salient features of PBL is that PBL problems are ill defined and somewhat ambiguous. While there are many differences between physicians and teachers, the fact that they are both required to assess and make decisions with incomplete information means that PBL, which has been effectively used in medical schools, may also be an appropriate method to use in teacher professional development.

The goals for learners participating in PBL include increased content knowledge, development of problem-solving skills, increased skill with professional decision-making, opportunities to collaborate with peers, enhancement of self-directed learning skills (Chernobilsky et al., 2004; Hmelo-Silver, 2004; Kelson, 2004), and increased intrinsic motivation for learning (Hmelo-Silver, 2004). In any context, the question of how to accurately assess the intended learning outcomes of students in a PBL context has yet to be definitively answered. In the Dochy, Segers, Van den Bossche, & Gibels (2003) study, the authors suggest that the types of assessments used influenced the results; students who were asked to construct responses to open-ended questions showed higher gains. Hmelo-Silver (2004) has also demonstrated that traditional measures like multiple-choice tests may not be suitable to assess the type of deep, flexible knowledge that PBL fosters.

To date, there has been little work on using PBL as a tool for teacher professional development, although there have been studies of teachers who were taught to use PBL in their classrooms. For example, Sage (2001) presented a summer graduate course for teachers designed to help them develop PBL modules for their own classrooms and collected self-report data from these teachers. These teachers reported increased enthusiasm for teaching, a change in their teaching practices, and a difficult but stimulating learning experience. Self-reported changes in their teaching practice included taking a more constructivist view of the teacher's role, greater consideration of critical thinking, and increased use of authentic assessments. Like Sage, we were interested in measuring the impact of this model of professional development on teachers' practice. In addition to measuring the impact on practice, we used design-based research to examine how and whether components of the professional development model influenced teacher knowledge and practice.

PBL Designed to Develop Teachers' Science and Pedagogical Content Knowledge

Effective teaching requires reflective practice – teachers must assess, diagnose, prescribe, and adjust their practice to reflect ever-changing circumstances as well as new research, knowledge, and experience. Recognizing the teacher as a reflective practitioner requires professional development (PD) opportunities that change to meet teachers' needs over the span of their career. This project includes both preservice and inservice components and has two goals:

a) Develop, implement and study the impact of a subject matter-focused, problem based learning professional development model.

b) Design ways of incorporating problem-based learning into key subject matter and teacher preparation courses taken by preservice teachers, and study the impact on preservice teachers' learning.

The preservice component takes place in undergraduate science education courses and post-baccalaureate courses that students take during their one-year internship, which is a requirement for teaching certification. Thus far, problem based learning has been incorporated into 3 science courses and 3 science-education courses for preservice teachers, and individual faculty who teach these courses are studying the impact through research in the context of their coursework. This paper focuses on the inservice component of the project. Many of these teachers serve as cooperating teachers for our preservice teacher education program, so their professional development has a long-term impact on the field experiences and the mentoring of preservice teachers.

In this professional development effort, PBL was used as a tool to help inservice teachers from local K-12 schools examine problems of science content and pedagogy in a self-selected content area. In their application for this professional development, teachers selected an area of science they found challenging (e.g., life science) and identified a unit they wanted to revise to increase student understanding (e.g., genetics).

Orientation to the project. One of our assumptions in developing this model was that teachers need modeling and practice with the PBL process. Thus, during orientation to the project, we introduced teachers to the project through the analysis of a PBL dilemma dealing with science content. A second assumption was that teachers needed to carefully assess student understanding in order to redesign the unit they proposed working on in their application materials, so this revised unit would be based on knowledge of student learning. Thus, we collaborated with teachers in designing an open-ended task to measure student understanding of the concepts from the unit they wanted to revise, and asked them to give this assessment to their students both before and after the unit. Teachers also were instructed to assess student understanding using items from national and state assessments (e.g., NAEP items) focused on that particular area of science content. Finally, we wanted to ensure that the professional development was based on knowledge of teacher understanding, so we collected data on teachers' understanding of the science concepts for the unit. During the second night of the orientation to the project, we taught teachers to score both of the assessments they administered to their students, including the open ended assessment tasks using rubrics they designed. We focused on assessment so that teachers would be involved in assessing potential changes to student understanding based on revisions in their teaching practices and unit.

The PBL process. During the first year of the project, we studied how the PBL process was used in medical schools, in science classrooms and in teacher education courses. From our research, we designed the following process in which group members:

1) Encountered a new dilemma (most of the content dilemmas were text-based; the teaching dilemmas included both text and video-based dilemmas)'

2) Discussed their views of the problem;

3) Identified key information as it related to the problem;

4) Proposed hypotheses—what they thought might happen under certain conditions;

5) Formulated learning questions to investigate those hypotheses,

6) Investigated these questions, often using computer resources, as well as print and laboratory equipment,

7) Discussed and applied their new knowledge to the problem,

8) Synthesized their learning, integrating this with previously learned concepts,

9) Reflected on their reasoning process and the big ideas

10) Reflected on the group process and facilitation.

In general, the facilitator wrote the group's ideas on the board as the group discussed problems; however, at times the group members wrote ideas and posted those to the board. This process was introduced to participants during the orientation, and used during the summer sessions. Our assumption was that PBL could provide a framework for deepening content knowledge as well as pedagogical content knowledge, because group processing would allow teachers to articulate their ideas, refine their ideas and learn collectively. We are also hopeful that the simplicity and flexibility of the PBL process mean that teachers will continue to use it outside of the professional development experience. Between 4-7 content dilemmas were discussed in each science content group during the first week and a smaller number of teaching dilemmas were discussed by teachers during the second week of the summer seminar. During the school year, we followed this clinical reasoning process with the dilemmas created and presented by the teachers in their learning communities.

Creating PBL dilemmas. Despite the growing base of literature that describes problem-based learning, the amount of literature on the writing of problems for use in the PBL process is limited. In addition, because PBL has not been widely used with practicing teachers in professional development contexts, literature on the writing of problems for use with science teachers in such contexts is nonexistent. Although case-based and problem-based approaches are not identical, we used the literature on both case-based and problem-based materials because the literature pertaining solely to the development of PBL materials (i.e., the writing of good problems) is not substantial, and because many similarities exist between the two instructional approaches.

Writing Problems and Problem-based Cases

Several different sources list criteria for good case materials or good problem-based learning materials and, while none were identical, many had several features in common. We synthesized the literature to develop the following set of criteria for evaluating problems: authentic and relevant, pedagogical effectiveness, controversial, appropriately complex, clear about participants' roles, and engaging.

Authenticity and relevance. Authentic and relevant problems entail professional situations that participants are likely to encounter or describe situations of which participants are aware, and pertain to current issues of the profession (Herreid, 1997). They cause participants to empathize with the characters of the problem, and the decision-forcing moments of the problem are within the actual realm of powers possessed by the characters in the problem (Herreid, 1997). Similarly, authentic and relevant problems allow participants to play a role in the solution of the problem (Kelson, 2004). The context in which the problem is situated needs to be closely aligned with the professional context in which the learners will practice the knowledge and skills learned during the problem (Hung, 2006).

Pedagogical effectiveness. Many instructional approaches exist regarding the teaching of science content, each of which varies with respect to their requisite inputs (for example, time and materials) and their expected outcomes. To assess the pedagogical effectiveness of a PBL problem is to make a judgment regarding the appropriate commitment of resources in its use. Two considerations are made: first, whether a particular set of desired learning outcomes warrants the use of the PBL process, and second, whether the selected problem could potentially produce those learning outcomes. Pedagogically effective problems warrant the cost in terms of teaching and learning time and effort, and they foster the development of the intended outcomes of the PBL process (Kelson, 2004).

Controversial. Controversial problems provoke conflict and engender multiple, viable hypotheses about which reasonable people could disagree (Duch, Groh, & Allen, 2001; Herreid, 1997; Kelson, 2004). Controversial problems may include various competing, and equally valid, solutions (Harrington, 1995). They are ill-structured, ambiguous, and can be interpreted in many useful ways (Hansen, 1997).

Appropriately complex. Appropriately-complex problems require participants to locate information for themselves, using available sources (Delisle, 1997). Appropriately-complex problems provide only the amount of information that participants would really possess if they were actually encountering the problem situation (Kelson, 2004). Such problems require participants to engage in an appropriate inquiry process in order to reach the most reasonable solution and justify their decision, and the self-directed research phase should require rigorous, academic work (Levin, 2001). Such problems necessitate the collaboration of all group members in efforts to solve them. Without appropriate complexity and an ill-structured nature to the problem, depth of learning within the content domain will not be possible (Hung, 2006).

Clear about participants' roles. Problems that are clear about the roles of the participants have clear boundaries and naturally lead participants to a particular production or performance (Kelson, 2004). This should not be interpreted to mean, however, that the specific outcomes or product required by participants is so clearly specified (as it is in project-based learning) that it keeps them from having to set goals and make decisions (Savery, 2006). A problem that is clear about the participants' roles requires participants to make a decision regarding the resolution of the problem, justify their decisions, and reflect on the process of reasoning about the problem. Problems should provide explicit information about learning goals and intended learning outcomes in order to keep students focused on the primary knowledge to be learned, instead of allowing them to wander in other interesting peripheral topics (Hung, 2006). In addition, such problems specify the role of the learners as individuals who are stakeholders in the solution of that particular problem (Torp & Sage, 2002). Not only can participants empathize with the central character of the problem, they can also imagine themselves as the central character in the problem.

Engaging. Engaging problems retain the attention of the participants throughout the PBL process, thereby promoting the intended outcomes of the process. Engaging problems "stimulate curiosity, arouse interest, and motivate participants to probe for deeper understanding" (Herreid, 1997; Kelson, 2004). When presented with an engaging problem, participants become active learners who take a personal interest in the dilemma; such problems drive participants to consider alternative solutions and pursue the information necessary to make the best decision possible.

We used the above criteria to generate specific content and teaching dilemmas based on the participants' needs that we identified from the application materials and the orientation sessions. Facilitators practiced using these dilemmas with other members of the project and then revised their dilemmas prior to the summer seminars.

The summer seminars. During the first week, called the *Professional Working Conference,* about 50 teachers worked through *content dilemmas*, which were problems designed by facilitators to increase teachers' content knowledge in an area related to their self-selected content. Teachers were grouped by science content (Physical, life, earth) and by grade level (elementary, middle, high school), and each group focused on deepening science understanding through problem-based learning applied to science content dilemmas. During that week, teachers were given time to develop units to teach in their classrooms the following year, as well as gaining experience with inquiry and with designing problem-based learning activities. Our assumption was that effective curriculum is standards-based and follows a backwards design approach (Wiggins &

McTighe, 1998), so we encouraged teachers to carefully design assessment tasks and to think about essential understandings and big ideas in revising their units.

During the second week, called the PBL *Focus on Practice*, about half of the teachers who had participated in the in the first week stayed to work through *teaching dilemmas*, which were problems of teaching practice. In the first year we used both text or as video cases and decided to use only video cases in our second year. These problems focused on teaching issues, such as interactions with students, assessment, inquiry, and instructional decision-making. Current science reforms (American Association for the Advancement of Science, 1993; National Research Council, 1996) call for a pedagogical shift away from a teacher-centered approach and encourage a move towards student-centered instruction. In this reform-based vision of science education, the emphasis is on active science learning environments in which students are provided with opportunities to engage in both hands-on and minds-on learning experiences. Two key elements of student-centered instruction include engagement in inquiry, which involves interacting with objects and phenomena in the world and trying to make sense of these experiences through the development of patterns and explanations (Anderson, 2003), and social interactions with teachers and peers to develop students' scientific understanding. In these types of learner-centered environments, teachers pay close attention to students' prior conceptions and attend to their ideas both before and during instruction (National Research Council., 2005).

We assumed that teachers needed to incorporate student-centered instructional practices, such as inquiry and problem-based learning into their revised units. We also assumed that modeling and analyzing teaching episodes of other teachers would enable teachers to do this with their own teaching dilemmas and videotaped classroom episodes during the school year. During that week, teachers created and refined a teaching dilemma they wanted to research in the upcoming school year using PBL with a small group of teachers (their learning communities). To enable teachers to identify important issues in their practice to research, we provided guidance and feedback through the establishment of learning communities, that is, groups of 4-6 teachers of similar grade level and content interest (physics, earth, biology) who were in the same or nearby districts .

Monthly learning communities. The primary focus of these learning communities were the teaching dilemmas and associated research projects that teachers initiated in the second summer seminar, *Focus on Practice.* Teachers met monthly with one or two facilitators throughout the school year to study the problems of practice they identified during the second week of the summer PBL seminar. As individual teachers implemented their new unit plans and revised their practice, they used video as a tool for analyzing and reflecting on their practice, as well as student work. As each teacher presented her teaching dilemma and research to the learning community, teachers used the PBL process to engage in professional exchange of ideas. Change in practice is hard work and these teachers supported and challenged one another during this iterative approach to improving their practice. The culminating activity was a dinner and work session in which all participants presented their research projects based on their teaching dilemmas using a multimedia format to show both their practice and student work. In the chapter, *Science Teachers as Researchers*, Kathleen Roth summarized the four characteristics of effective professional development program (2007, p. 1206) which include: "1) Engage teachers actively in collaborative, long-term problem based inquiries; 2) Treat content as central and intertwined with pedagogical issues; 3) Enable teachers to see these issues as embedded in real classroom contexts; and 4) Focus on the content and the curriculum teachers will be teaching." These learning communities allowed teachers to extend the content and curriculum work they accomplished over the summer into the school year in a sustained context. Their peers (and the content facilitators) challenged teachers to collaborate using teacher research to inquire into problems of practice.

Research on this Model for Professional Development

In answering the question, "How effective is using Problem-based Learning as a model for professional development in science", we have posed research questions pertaining to the development of the model as well as questions regarding the impact of the model on teachers and classrooms. We are using design-based research, an iterative, evolving process of inquiry, in which we collaborate with teachers to study the design of this learning environment, make changes to the environment and create new designs for the learning environment based on results and theory. Design experiments that assess the implementation of learning environments in the context of actual classrooms or professional development contexts can develop understanding about the components of effective professional development that teachers report beneficial to their learning (Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003) (Rowland, 2007). These experiments also contribute to knowledge regarding changes in teachers' performance. I will summarize some of our findings on the impact of this model of professional development on teachers and our research on the development of this model of professional development.

Research On The Impact of the Model

One of our assumptions is that improved teacher practice will lead to improved student learning. We measured improved teacher practice through pre and post scores on the Horizon instrument (Weiss, Banilower, McMahon, Smith, 2001), and used concepts maps to gauge changes in teachers' content and pedagogical content knowledge. We have moved to examining changes in teachers' knowledge by using pre and post open ended questions before and after problem-based dilemmas so we can more directly see the influence of the PBL process on knowledge. We now also use tests of students' learning to judge the impact of the model on pupil performance, but have yet to analyze this data. In addition we examine the impact of this professional development on changes in student learning through collaborative teacher research: through research on their teaching dilemmas, teachers collect and analyze changes in students' learning.

Changes in teacher practices. Our primary concern was to improve teacher practice and classroom learning, so we asked this research question: Does this professional development have an impact on changing teachers' practice, and if so, in what ways?

According to the pre and post test scores on the Horizon instrument (Weiss, Banilower, McMahon, Smith, 2001), that measured self-reported changes in science teacher practices, teachers gain significantly on their preparedness to use standards-based teaching practices, $t = 2.9$, $p = .011$. These items asked teachers how prepared they are to do the following: Develop students' conceptual understanding of science; provide deeper coverage of fewer science concepts, make connections between science and other disciplines, lead a class of students using investigative strategies, have students work in cooperative groups, listen/ask questions as students work in order to gauge their understanding. They also reported using fewer traditional teaching practices, $t = 2.488$, $p = .026$, such as having students answer worksheet assignments, and reported using more extended projects and investigations, 2.280, $p = .040$. This included designing investigations, having students work on projects that were a week or more in duration, participating in fieldwork, using peer evaluation. Teachers also reported using more informal assessment, such as asking students questions during large group and small group discussions, or other assessments embedded in class to check student understanding. Finally, teachers also gained significantly on their preparedness to use computers practices, $t = 2.280$, $p = .040$, such as simulations and applications.

Kathleen Roth (2007) noted that when reporting positive outcomes of teacher research on inservice teacher's learning, "most are careful to limit the claims to changes in teacher beliefs, knowledge, and analytical abilities, rather than changes in teachers' practice and their students' learning" (p. 1219). Measuring changes of teachers' practice using Horizon is a strength of our research program (Weiss, Banilower, McMahon, Smith, 2001); however, it is not sufficient. We also analyzed teachers' practice through the student work they produced in their classrooms, through their teacher research on their teaching dilemma, through our own observations of their practice in their school classrooms, and interviews with teachers.

These results regarding changes in teacher practice corroborate our observations of teachers in the project and the gains teachers report in interviews and in their writing. For example, one teacher wrote, "The implementation of problem-based learning in my classroom has been supported by the interest level of students using the process. PBL is an engaging way to interest students in science. I have few discipline issues, students interact and learn together and share ideas. I feel successful as a teacher when I think about all of these positive outcomes of using PBL in my classroom." By observing individual teachers in their classrooms, Lindsey Mohan and Mary Lundeberg are beginning to document the critical role discussions play in supporting students as they learn science and to understand how these teachers engage students in practices that support the goals of science. Meilan Zhang, Jeannine Stanaway and Mary Lundeberg are analyzing the interaction and discourse that occurs during PBL professional development sessions to learn more about how facilitation influences teachers' knowledge and practice.

Changes in teachers' content knowledge and pedagogical content knowledge. Another primary goal centered on deepening teachers' knowledge, so asked a second research question: How does participation in a problem-based learning professional development program impact teacher-participants' content knowledge? In this study (Weizman et al., 2006) we evaluated the effectiveness of a problem-based learning (PBL) approach to professional development (PD), using concept maps as the main method.

We chose to use concept maps as the main assessment method, because each teacher was focused on improving a different science unit and concepts maps allowed us to measure individual differences in conceptual understanding and pedagogical content knowledge of science teachers. Because PBL emphasizes contextual richness and the development of conceptual connections, we decided that evaluation instruments that do not emphasize context and connections (e.g., multiple-choice questions) would be inappropriate for measuring change in teachers' science content and pedagogical content knowledge (Hmelo-Silver, 2004).

According to Shulman (1986), PCK is comprised of the synthesis of three knowledge bases: subject matter knowledge, pedagogical knowledge, and knowledge of context. Shulman (1986) wrote that PCK includes knowledge teachers should have about how to help students understand specific subject matter. It includes content and pedagogy that provide teachers with an understanding of how particular subject matter topics, problems, and issues are organized, represented, and adapted to the diverse interests and abilities of learners, and then presented for instruction.

Magnusson, Krajcik, & Borko (1999) view pedagogical content knowledge and beliefs as the result of a transformation of knowledge from other domains, including subject matter knowledge and beliefs, pedagogical knowledge and beliefs and knowledge and beliefs about context. The relationships between these domains and PCK are reciprocal. These authors further define the concept of PCK as including 5 components: orientations toward science teaching, knowledge and beliefs about science curriculum, knowledge and beliefs about students' understanding of specific science topics, knowledge and beliefs about assessment in science, and knowledge and beliefs about instructional strategies for teaching science. Here we adopt these categories, and modify them to the purpose of evaluating the PBL workshop. We operationalized each of the 5 categories using indicators related to the content discussed during the PBL PD workshop. We hypothesized that concept mapping, which allows participants to include context and encourages the inclusion of connections among concepts, could be an appropriate assessment tool for this PBL professional development study (Ruiz-Primo, Shavelson, Li, & Schultz, 2001).

We analyzed this development in science teachers' understanding by comparing pre-test and post-test concept maps of both content knowledge and pedagogical content knowledge created at three time points: beginning of each summer seminar, end of each summer seminar and at the end of the school year. We found that participants developed understanding of several components of pedagogical content knowledge, and had a strong positive impact on two of the five components of pedagogical content knowledge. As a result of participating in the workshop, teachers were more likely to indicate that curriculum knowledge and assessment are important aspects of effective science education to consider and include in their teaching practice. By the end of the year the pedagogical content knowledge of these teachers had significantly changed. Concerning the development of content knowledge, results were positive for one subject matter group (physics), and not significant for others (earth science or life science). We concluded that the PBL approach to PD may be effective for developing specific components of PCK of science teachers, but its influence on content knowledge is still not clear.

Research On The Development Of The Model

We assumed that because we were charting a new path for teacher development, we had much to study about several components of this model of professional development, including the design of the content and teaching dilemmas, the facilitation of the problems, and the design of the learning communities. For example, one of our first studies related to the design of the content dilemmas (Oslund et al., 2006).

Design of content dilemmas. In this study, we synthesized the literature on the writing of effective problem-based learning materials to develop a framework for evaluating such material. Using the framework, we investigated how differences in the characteristics of four content dilemma problems may have led to different learning opportunities for teachers and influenced their perceptions of the usefulness of the problems during this professional development project (Oslund et al., 2006).

. We analyzed participant surveys, facilitator board notes, and videotapes of the problem-based learning discussions, and found that problems aligned with our criteria in the framework led to more opportunities for self-directed learning, problem-solving, and collaboration. We concluded that our framework is useful for evaluating materials for use in problem-based learning contexts.

Design of teaching dilemmas. In a similar vein, we asked whether the amount of structure in a teaching dilemma influenced teacher learning (Mikeska, Koehler, Weizman, & Lundeberg, 2007). The purpose of this study was to examine 1) whether the use of teaching dilemmas helps teachers consider instructional strategies and move towards a more student-centered pedagogical orientation and 2) how the structure of the problem affects participants' thinking and performance in analyzing teaching dilemmas during a problem-based learning professional development seminar for K-12 science educators. In one case, we stated the teacher's problem of practice, or teaching dilemma, while the teachers in the other group had to identify the problem(s). We used a grounded theory approach to analyze teachers' responses to a pre- and post-assessment question and the charts constructed during each group's problem-based learning experience. Although teachers in both groups moved towards a more student-centered teaching approach, those in the less structured group generated more ideas about instructional strategies after encountering the teaching dilemma. Teachers in the less structured group had a richer discussion that involved questions regarding the nature of science.

Strengthening reflection within learning communities. One of the questions we had in the first year of the project was whether to require teachers to video as a tool for reflection on their classroom practice as it related to the teachers' dilemmas and research projects, so we posed this research question: Is video a more powerful tool for teacher reflection on problems in their practice than talking and writing about their practice? Teachers were randomly assigned within each learning community to use videotaped records of their practice or to use only text-based materials for reflection. The text group used written observations and summaries as the basis for their self-study and reflection. The video group used video-taped records of their teaching to guide their reflections.

As part of the PBL Project, teachers from a range of grade levels answered questions on the Science Teaching Efficacy and Beliefs Instrument (STEBI) (Riggs & Enochs, 1990). Bandura describes two components of self-efficacy: outcome expectancies and self-efficacy expectations of the teachers (Bleicher, 2004). The STEBI survey includes instruments that measure both components. The Science Teaching Outcome Expectancy Scale (STOE) measures a teacher's beliefs that his or her teaching will be successful in producing the desired outcomes in students. Eleven of the twenty-five questions on the STEBI instrument comprise the STOE subscale (Riggs & Enochs, 1990). The Personal Science Teaching Efficacy Belief Scale (PSTE) consists of twelve survey items. The PSTE subscale assesses a teacher's beliefs about his or her own ability to effectively perform science-teaching behaviors (Riggs & Enochs, 1990).

We concluded, based on changes in STEBI survey data that the PBL professional development had a greater impact on teacher's sense of self-efficacy for teaching science when teachers' reflections were based on videotaped records of practice than for teachers who reflected on written records of practice. There were significant differences between the text and video groups for both the outcome expectancy and teacher efficacy belief components of self-efficacy. Teachers developed a greater sense of confidence in their ability to teach effectively and a stronger belief that their teaching of science would result in student learning when they used video to reflect on their practice in these learning communities. Such an increase in teacher self-efficacy has been linked to greater teacher effort and willingness to experiment with new teaching strategies and materials (Tschannen-Moran, Wolfolk Hoy, & Hoy, 1998). Tom McConnell is examining the videotaped sessions from these groups to see how interactions between the text and video groups may have differed in order to account for this increase in efficacy in the teachers who used video.

The power of choice and learning communities. Finally, through teacher interviews we are asking questions about several components of the professional development to analyze what components of the model teachers think has impacted their practice. According to the evaluation data (interviews) we have collected, teacher respondents found the PBL professional development beneficial because it gave them time to focus, collaborate and develop units. Giving teachers choices –both in their focus on a science unit, and in their research on their teaching dilemma—seemed to motivate and energize the teachers. Teachers also chose the kind of student-centered activities they wanted in the unit they redesigned. We found that many teachers embraced problem-based learning, rather than showing resistance to these ideas, as others have reported in professional development projects that require teachers to teach using problem based learning (Ertmer & Simmons, 2006). Teachers also reported benefiting from the research of other teachers in their learning communities and found the sharing, support, feedback and problem-solving associated with their on-going work helpful. Although most teachers indicated they applied the PBL approach to developing additional units during the school year, several teachers still needed additional help in devising good questions/problems. Facilitation of problems is a challenge for teachers as well.

In summary, we have created a model of professional development for science teachers using problem-based learning as a framework for deepening content and pedagogical content knowledge. We have found that it is challenging to measure changes in teachers' content knowledge, given the flexibility of this professional development model. However, our results suggest that teachers are gaining pedagogical content knowledge, are using more standards-based, inquiry in their teaching practices, and benefit from the collegial nature of the learning communities. Changes in student learning resulting from changes in teacher practice is complicated to assess, and we are just beginning to analyze this data.

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