The Influence of Problem Based Learning Professional Development on Science Teachers' Pedagogical Content Knowledge

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Abstract

In this case-study, we follow two elementary science teachers, who took part in a year-long professional development program designed around Problem Based Learning (PBL). We examine how each part of the program influenced changes in the different components of the teachers' Pedagogical Content Knowledge. Triangulation of many data sources (concept maps, written work, interviews, videotapes, etc.) indicated that both the summer workshop and the small-group learning community meetings throughout the year influenced some change. For the teacher whose initial orientation was highly teacher-centered, with high self-efficacy we found change mainly in one component - knowledge of assessment, which occurred only after his students' outcomes contradicted his expectations. The teacher whose initial orientation was more student-centered and her self efficacy was low, experienced major development in several PCK components, influenced by several parts of the program. The main outcome for both teachers was the ability to use the PBL process to solve dilemmas in their own practice.

Creating effective professional development and linking it to changes in teachers' knowledge and beliefs is a challenge that researchers still struggle with, even though different models had been suggested (Loucks-Horsley et al., 2003, Fishman, Marx, Best and Tal, 2003, Kubitskey and Fishman, 2004). These models try to influence and assess changes in teachers' content knowledge and pedagogical content knowledge (PCK). Evaluation of pedagogical content knowledge (PCK) is complicated (e.g. Kagan, 1990), and conventional assessment methods are not suitable for integrating all aspects of PCK. The initial definition of pedagogical content knowledge by Shulman (1986) was later clarified by others (e.g. Veal & MaKinster, 1999; Segall, 2004), expanded to include new components (e.g. Barnett and Hodson, 2000; Magnusson, Krajcik, & Borko, 1999; Mishra & Koehler, 2006), and investigated among teachers (e.g. van Driel, Verloop, & de Vos, 1998; Jones, Rua & Carter, 1998).

Magnusson, Krajcik & Borko (1999) defined five components of PCK: (a) orientations toward science teaching, (b) knowledge and beliefs about science curriculum, (c) knowledge and beliefs about students' understanding of specific science topics, (d) knowledge and beliefs about assessment in science, and (e) knowledge and beliefs about instructional strategies for teaching science.

The component “orientations toward science teaching” include teachers’ knowledge and beliefs about the purposes and goals for teaching a specific science topic at a particular grade level, that guide their instructional decisions. Empirically, however, teachers can hold multiple orientations, including ones that seem incompatible, such as didactic and inquiry. Theoretically, teachers’ orientations inform their understanding and practice of the other 4 components of PCK. It is likely that science teachers would change their orientations based on particular contexts. In this study we examine how the different PCK components for two teachers changed during one year of continual professional development. This continual sustained professional development was based on an approach called problem-based learning (PBL), which views teachers as clinicians who reason about dilemmas in their teaching.

The PBL PD model

Problem-Based Learning (PBL) mirrors the clinical reasoning process required by professionals who make decisions with incomplete information (Hmelo-Silver, 2004). Problems (often ill-structured) are presented to learners, so they develop and apply contextualized knowledge in solving them. Despite widespread use of PBL models for learning in contexts such as medicine, law, and business, relatively few people have used PBL in teacher professional development. Sage (2001) suggests that a PBL approach to learning helps teachers develop a viewpoint that increasingly values critical thinking, constructivist approaches, and the use of authentic assessments.

The PBL process includes several components: identifying the problem and the facts, generating hypotheses, self-study and research of resources, group discussion, conclusion, reflections and recommendations.

The main theme of the project is that teachers are professional practitioners. Our main goal is to improve science education, with the teachers playing an active role and taking responsibility in all the components of the PD.

The PBL model that we developed is based on the following assumptions:

1. PBL could provide a framework for deepening content knowledge as well as pedagogical content knowledge.
2. Improved teacher practice will lead to improved student learning.
3. The simplicity and flexibility of the PBL process will enable teachers to continue to use it outside of the professional development experience.
4. Teachers need modeling and practice with the PBL process.

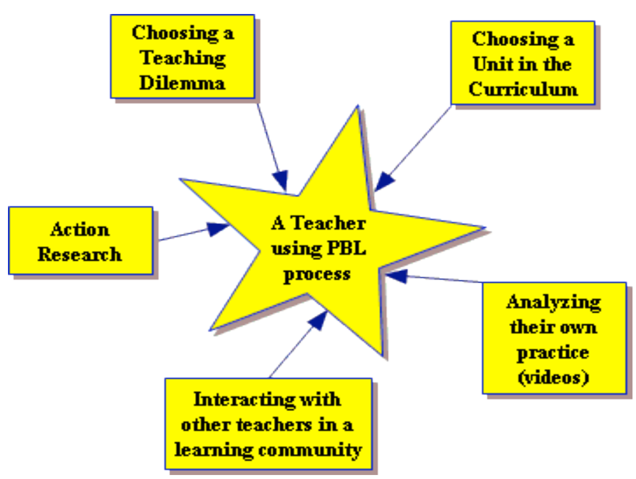

Figure 1 - the teacher role in PBL PD

5. Teachers need to carefully assess student understanding in order to redesign their unit based on knowledge of student learning.
6. Effective curriculum is standards-based and follows a backwards design approach (Wiggins & McTighe, 1998).

The developed model includes four main parts: 1. Orientation meeting, 2. Summer workshop, 3. Monthly meetings, 4. End of year session

The orientation meeting serves both for collecting initial data, and for introducing teachers to the PBL method. During the summer workshop teachers practice the PBL process. The first week focuses on developing content knowledge through practice of PBL content dilemma (see Oslund et al. 2006), and the second week is focused on PCK development through practice of examples of teaching dilemma (see Mikeska et al. 2007). At the same time each teacher chooses a “Teaching Dilemma” – a problem identified from their own practice. They begin to explore this dilemma in the workshop, and continue to research it during the year. Groups of 3-5 teachers meet monthly with a facilitator, who mediates this learning community, going through the steps of a PBL process (see figure 2). As part of this process, teachers use their classrooms as a site for research into their dilemma, and videotape the relevant lessons. Participants analyze their practice and then present their analysis to their group for further reflection using a PBL lens. At the end of the year each teacher prepares a poster presentation of their dilemma, the hypothesis, results and conclusions they found.

The following chart summarizes the connections between the model different levels, and data collected along the different parts:

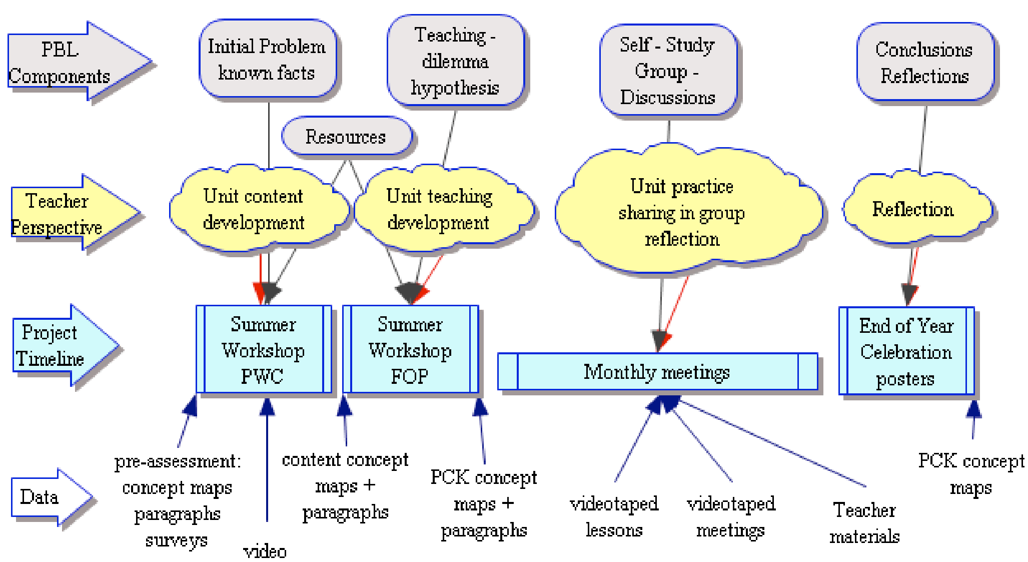

Figure 2 – different levels of the PBL PD

In this study, we were interested in following individual teachers to learn more about this research question: How did each part of the PBL PD affect the teachers' PCK components along the year?

Method

Participants

This study focuses on two of the sixteen teachers who participated in all the components of the PBL PD project in the first cohort (2005-2006). We selected these teachers because they both chose to concentrate on the same topic- a unit about the Earth, Sun, and Moon, and approached this unit in very different ways. Both teachers were intermediate-level elementary teachers, who differed in school settings, and background in science. Linda[1] taught a group of five 3rd and 4th grade students in a small elementary private school, and had limited background in science. John[1] taught 5th grade, and had a more extensive background and experience in science teaching.

Procedure and Instruments

We triangulated data collected during the different parts of the PD – the summer workshop, monthly group meetings, individual work on the unit and teaching dilemma, presentations and final posters across the year. Figure 2 indicates the instruments and the time they were collected. In addition, we interviewed one of the teachers a year later.

Concept maps of "effective science teaching", and paragraphs explaining the maps, were created at the beginning of the summer workshop, after the second week of the workshop, and again during the end-of-year celebration. Participants were asked to describe an episode in a classroom of an effective and engaging science teacher, teaching a topic in their unit.

Analysis

As described in Weizman, et al. (2006), we used qualitative methods to analyze the content and PCK concept maps. Previously we coded the PCK concept maps, using a formulation based on Magnusson et al (1999). We used this same coding scheme in this study, to analyze other data (paragraphs, transcribed interviews, and transcribed videos). This analysis provided information about how the PCK components of each teacher developed during the different parts of the PD. Changes in knowledge and beliefs reported through interviews are compared with data from the videotaped lessons and triangulated with written work.

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[1]A Pseudonym

Results

The results regarding changes in PCK components for John and Linda are presented by four parts, based on the main components of the PD model: 1. Initial state, 2. Influence of the summer workshop, 3. Influence of Meetings and Practice, 4. Long term influence

1. Initial State

John

John's initial orientation, as provided by his initial description of "effective science teaching" in a paragraph following his concept map, illustrates a lesson centered on the teacher. The teacher is "*working the audience…like a comedian or salesman*" to create the atmosphere to engage students, e.g., using a "hook". His pre-test concept map has no mention of assessment and of student knowledge, but emphasizes instructional strategies and mentions the learning environment and preparation of lesson plans.

According to John's application, his goal in working on this unit was to develop more activities and demonstrations in order to increase the rate of student learning, and his interest to work with other teachers was "*so as to gain from their expertise."*
His initial self-efficacy is high, including considering himself as a "master science teacher", although in response to some survey questions he chose "needs attention" for his own understanding of the big ideas and how concepts build in this unit. He thought his main contribution will be his enthusiasm about science: *"I teach with great enthusiasm. I am constantly searching for better techniques. I really enjoy teaching science."* He admitted he had no previous knowledge about problem based learning.

Linda

In her pre-test PCK concept map and paragraphs, Linda emphasized the importance of pre-assessment of students for an effective science teacher in order to learn about students' knowledge, and inform her instructional decisions: "*after the teacher has read the answers to the questions she will be able to adjust the first lesson once she has established what her students know*". She also mentions the importance of knowing the materials and using resources, and of engaging students with activities. Initially, Linda's orientation to teaching was somewhat student-centered.

Similar to John, Linda's main goal in working on the earth and space unit was to improve her students' content understanding, based on what she wrote in her application. Her initial self-efficacy was low, declaring she did not consider herself as an effective science teacher, and did not enjoy very much teaching science. She wrote she would like to work with a team of teachers, based on her previous experience with a group that learned from each other. Unlike John, Linda had some previous knowledge about problem based learning.

2. Influence of the Summer Workshop

In a study evaluating the influence of the summer workshop on teachers' content knowledge and PCK by analysis of concept maps (Weizman, et al. 2006) we found significant changes in teachers' understanding of assessment and science curriculum, but not in content knowledge of a specific topic. In interviews, both teachers emphasized the importance of the summer two-week seminar to their learning.

John

Analysis of videos from the first week of the summer workshop, when John and Linda discussed PBL dilemmas in astronomy, shows that John has more knowledge than other teachers, assuming a leading role in the self-directed study part. In his interview John described his role at this part as *"good feeling to be a leader"*. Nevertheless, an analysis of workshop videotapes shows that when he expressed a misconception or didn't know something, it was difficult for him to admit it. John mentioned in the interview that he mostly learned from this part of the project, but his concept map and paragraphs at the end of the week do not show a significant change in content knowledge.

John's paragraphs provide information about his new thoughts and reflections about different aspects of assessment following the workshop*: "I need to focus more on using assessment for other reasons…like readjusting the lesson to accommodate misconceptions"* In the other components of PCK John's concept map and paragraphs do not show considerable change, and there is no evidence for change in his orientation to science teaching.

Linda

Linda's PCK concept map and paragraphs done by the end of the workshop show some important development compared to the pre-concept map. It includes more levels and details, and presents some new central ideas. Consequently, it was rated higher than the pre-test map in the components: curricular knowledge, Assessment, Instructional strategies. The change in curricular knowledge is interesting, considering that Linda's content-knowledge maps showed a very small content development, and many big ideas were missing from her paragraphs. There is some evidence for development in Linda's orientation to science teaching, becoming less didactic and more Inquiry oriented, for example: *"I found that even though the inquiry lesson does take longer, I feel that the students have a greater opportunity to learn"*. In the description of an effective science teacher she mentioned the use of questioning as assessment tool, and the use of assessment to "adjust the lesson". Another important subject that appears in Linda's paragraphs is reflection about the PBL process and what she learned from it. While reviewing her concept maps she writes: *"Now I know of a more effective way to pinpoint weaknesses and eventually be able to overcome these dilemmas through the PBL process…I do believe I have a better picture of good science teaching, and I will be able to pinpoint problems quicker and be able to change my teaching strategies rather than muddle through knowing that something is wrong, but not having the tools to fix the problem."*

3. Influence of Meetings and Practice

After the summer workshop, teachers were divided into small content-oriented groups with facilitators (around 5 participants in a group) for the monthly meetings. John and Linda were in the same group with other elementary school teachers whose unit focused on earth and space, and physics. The participants were randomly assigned to present their teaching dilemma to the group, either as a written case or as an analysis of videotaped lessons. John was randomly assigned to present written analysis of his teaching practice, while Linda was assigned to present video-based analysis. They were the first to present a written and video dilemma in their group.

John

John's dilemma title was: "How to implement better open-ended, thought-provoking questioning techniques to improve science learning in a 5th grade classroom while teaching an astronomy unit." He said he chose this topic because "I needed something measurable and narrow enough to determine if I'm meeting my objective". His presentation on his practice (he was the first) was very impressive, reflecting a complete PBL process (dilemma, hypothesis, self-study of resources, results and conclusions including reflection), and the group participants were engaged and interested in the topic. John reported that his higher-level questions resulted in excellent answers and more thinking of students (based on his memory of what happened in the classroom). He said *"I'm feeling pretty good about how I taught this unit"*. However, his evidence for student learning consisted only of some examples of students' interesting questions and answers (he presented before he completed the unit, and did not perform embedded assessment), and his inferences were mainly based on feelings and memory.

According to the researchers' analysis of the videotaped lessons in John's class, he missed important opportunities for embedded assessment. Most of this 5th grade lesson about "The Seasons" was teacher-centered, with the teacher demonstrating activities and asking questions. Although the participation level was high, it is not clear if students connected the discussion to the learning goals. The inquiry activities in this lesson, while "hands on activities", were not connected to class discussion. One example reflecting his teacher-centered orientation at this time emerged when a student raised her hand to ask a question. Instead of allowing the student to ask her question, John asked the student to go out of the class for a minute, then tried to predict the question, and asked her to come back. The actual question became less important compared to his "performance" in determining if he guessed her question correctly.

In the interview, John reported that group meetings were less helpful than the summer seminar. He was not satisfied being in a group with K-5 teachers, and would prefer it to be of the same grade level, because his colleagues: "…don't place importance on science as I do… some of them chose dilemmas they couldn't test objectively." He mentioned as especially helpful only one of the later group meetings, in which his assessments were discussed. When he reviewed his students' tests (post assessment) John was surprised by the results: "The test results were disappointing, it didn't support my intuitive thinking." He brought these assessments to the meeting, where the group, with the facilitator guidance, explored the tests and gave John feedback about possible difficulties. He concluded: "The (test) questions and illustrations weren't as well presented as they could have been to get the results… some of my friends [other teachers in his learning community] said that they confused the students… and maybe I thought that the lesson was better than what it was." Interestingly, in the last (third) concept map, which was done at the end of the year, he added a group of nodes around Assessment: pre-assessment, questioning and creative ways of assessment, that were not present in earlier concept maps. When asked in the interview why he didn't use his questions for assessment he replied that it's subjective and not objective. These findings indicate that the PCK component - knowledge of assessment - was influenced at this stage, although there was no indication of actual change in John's practice.

Linda

Linda's dilemma was "How will I make the best use of resources, visual aids, student involvement, etc. that will motivate my students to move from concrete experiences to abstract reasoning?" she incorporated in her unit activities, literature research, group projects, discussions and presentations, adjusting it for a small class (5 students) with mixed grade levels. Observation of her videotaped lesson indicates evidence for student learning and engagement, although there was no systematic embedded assessment. Linda was the first in her group to prepare a video presentation, and she had technical problems, as well as lack of knowledge of video analysis, that influenced her presentation. She presented many segments with little analysis nor focus on evidence to support her hypotheses.

Linda's experience of the group meetings was positive. She mentioned these meetings as one of the main components that influenced her teaching. In the second interview she described evidence for changes in her practice following what she learned from her colleagues during the group meetings. For example - using questioning techniques that were presented by John.

4. Long-Term Influence

Both John and Linda decided to return to the PBL PD a year later, for the third cohort. The main reason was their interest in working on another unit. The interviews by the end of the year, and for Linda also a year later, provide the main source of information for reflections on the project.

John

When asked if he would continue to use what he learned in the PBL PD in the future, John replied*: "I would definitely use the method of questioning in other units, but the PD was very demanding…I think I got more* out *of exploring my dilemma than adopting the PBL. I didn't do it in the classroom but for myself…I would do it for myself, not formally but informally, it's there on my brain."* This sentence reflects his appreciation of the PBL process as a possible way to solve dilemmas in his practice.

Linda

In her interview a year later, Linda presented evidence for changes in all the PCK components. She described how her practice changed in this year, and her science teaching improved following the PBL PD. For example: "*I realized in PBL that there are so many things you can use… that's what helped me to be more effective*"(knowledge of instructional strategies) . *"I felt I was very ineffective with assessments with only teaching 2 days a week… there just wasn't enough time to effectively teach the children. So in PBL I learned how to be able to do that."* (knowledge of assessment). "*A good science teacher has got to know what is going on with each child."* (knowledge of students).

Her report reflects a transition in her orientation toward more student-centered one: *"If I hadn't used problem solving I would probably told the kids: this is the way you do it. but I decided to let them to do some observing and playing around to see how it operates. that was productive. I wouldn't have done it that way if I wouldn't have gone through the PBL PD. I would have tried to be "the educator" instead of letting them find out on their own, and I believe they are going to remember it. If they find out on their own they are going to remember things more than me just telling them."*

She also reports improvement in her self-efficacy, corroborating the change in her scores in self-efficacy on the STEBI survey: *"I have a feeling, as a teacher I have a much better feeling than I did before. more confident, knowing that I got some tools to use…"*

For Linda, the main outcome from the program was learning to use PBL to solve dilemmas in her practice: *"The main advantage was using PBL in my own teaching, not necessarily science. to realize that if there is some sort of dilemma, rather than continue to teach ineffectively I can change that and I have the power to do that"*.

Conclusions

John viewed himself as a professional, and intended to engage in the PBL process as an objective researcher. The PBL PD did not affect his practice significantly, until his high self-efficacy was challenged when the assessments did not meet his expectations. Only then a change was observed in his PCK, in the knowledge of assessment component. At this point the community of practice influenced his understanding.

Linda was more open to changes in her knowledge, and consequently her PCK, as well as her practice, were influenced sooner and in more PCK components then John.

In long term it appears that the influence of the workshop decreases, and the main influence, the knowledge that teachers retain, is the ability to use the PBL process to solve dilemmas in their practice, and what they learned from their peers in the meetings.

Some implications for PD are that learning communities can provide support for teachers to implement new teaching practices, but that these small group communities need careful facilitation in order to influence teachers with various initial orientations.

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