INFLUENCING PEDAGOGICAL CONTENT KNOWLEDGE OF INSERVICE TEACHERS THROUGH PROBLEM-BASED LEARNING

Tom J. McConnell,
Jeannine C. Stanaway,
Joyce M. Parker,
Jan Eberhardt,
Mary A. Lundeberg,
& Matt J. Koehler

and the staff of the PBL Project for Teachers

Contact info for first author:
tommac@msu.edu

Problem-Based Learning Project for Teachers
Michigan State University

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Abstract

This study examines the influence of literature research and discussion with peers on the development of science PCK in elementary teachers engaged in problem-based learning as a professional development activity. The participants included 18 teachers from grades K-6 who had enrolled in an extended PD program focusing on science content, unit development and collaborative analysis of teaching practice. Data included pre- and post-assessments of their ideas about effective teaching related to two different videotaped teaching episodes. One episode asked teachers to write about instructional decision-making, and the other episode asked them to respond to a question about promoting student interactions. Teachers' responses were coded to identify the emergence of new ideas on post-assessments. The new ideas were then traced to discussions that took place during the activity in order to find sources of the new ideas. Teachers derived most of their new ideas from comments from peers about their personal experiences. Teachers based their new ideas on educational research much less frequently as a source of new ideas. Beginning teachers were more likely to use research than experienced teachers. Discussion of results includes the role of teacher culture and lack of experience in reading educational literature. The findings have implications for the planning of professional development activities.

Influencing Pedagogical Content Knowledge of Inservice Teachers Through Problem Based Learning

Introduction

Problem-Based Learning, or PBL, is a teaching strategy that was originally used to develop students' content and application knowledge in the medical fields (Albanese & Mitchell, 1993; Barrows & Tamblyn, 1980). In recent years, PBL has gained popularity as a method for helping learners in the science classroom to develop both content knowledge and critical thinking skills in students from a wide range of subjects and grade levels (Allen, Duch, Groh, Watson, & White, 2003; Capon & Kuhn, 2004; Chernobilsky, DaCosta & Hmelo-Silver, 2004; Gordon, Rogers, Comfort, Gavula, & McGee, 2001). These studies suggest that learners gain content knowledge, but a more significant effect is the increase in the student's ability to apply concepts to real-world contexts.

Very little research has been done, though, on the use of PBL as a tool for increasing teachers' content and pedagogical knowledge. Since teachers can be viewed as clinicians who make multiple decisions about practice during the act of teaching science, just as medical professionals do in their practice, PBL is likely to be an effective strategy for helping educators construct the pedagogical knowledge needed to teach science more effectively. The PBL Project for Teachers is a research and teacher education program at a major university in the Midwest that uses PBL to help K-12 teachers develop both science content knowledge and critical reasoning skills (Torp & Sage, 2002) in the context of teaching science lessons.

The PBL Project for Teachers includes two phases: the Professional Working Conference (PWC) which was devoted to teachers' content learning and unit development, and the Focus on Practice (FOP), in which participants analyze videotaped teaching cases using a problem-based learning (PBL) framework. Participants then developed questions about their own unique teacher practice for analysis during the following school year using the same learning framework. An explanation of the PBL framework can be found in the appendix attached to this article. The PWC workshop was focused on using PBL to help teachers learn science content from areas of their choosing. Teachers then applied their new content understandings to the development of units for their own classroom use. The goals of the FOP workshop were to influence teachers' orientation toward science teaching (Weizman, Lundeberg, Koehler, & Eberhardt, 2007) and to develop new understandings of pedagogical decisions made in the science classroom. As such, the PBL Project worked to develop teachers' pedagogical content knowledge (PCK) as teachers engaged in analysis of their practice for a year or more.

Science pedagogical content knowledge (Shulman, 1986) is the intersection between content and pedagogical knowledge that allows teachers to select appropriate strategies for effectively teaching science. Schön (1983) described teacher reflective practice as a method for accelerating and refining teacher's professional reasoning skills. He suggested that teachers need to *reflect on practice* (p. 51) in order to develop the ability to *reflect in practice* (p. 53), his term for the act of making decisions in the midst of teaching that Shulman includes in his description of PCK.

Shulman's definition of PCK involves the ability to make decisions based on the needs of students in the midst of practice. These decisions involve selection of appropriate strategies for helping learners in a given context understand the desired concepts. Another way to view PCK is as the ability to make clinical decisions to diagnose the needs of learners and plan for meeting those needs. Because it has been effective in helping medical students learn to think critically, PBL Project planners selected problem-based learning as a strategy to help teachers develop this type of clinical reasoning ability.

This study uses a social constructivist orientation (Vygotsky, 1978) to examine the contribution of participants' discourse to the creation of new teacher knowledge in the context of a PBL teacher professional development activity. We attempt to identify which activities of the PBL program contribute to teachers' construction of pedagogical content knowledge.

The PBL Project for Teachers engages participants in reflection on practice through analysis of video-taped cases (Mikeska & Stanaway, 2006) in order to help teachers develop science PCK. Participants were asked to write responses to a question about science teaching practice before viewing two different teaching episodes. One of the episodes, titled "Circuits," asked teachers about effective strategies for dealing with conflicting evidence and students' misconceptions in a science experiment. The second episode, "Falling Objects," asked teachers to write about strategies for promoting student-to-student interactions. The two questions provide a specific "lens" to help participants focus their attention on one aspect of the teaching episode. The episodes were then presented to the groups as PBL scenarios, or "dilemmas," and the group's task was to analyze the episode and make recommendations to the teacher. After viewing a videotape of a classroom, participants identified a problem to be addressed, discussed the events seen in the video and identified learning issues and hypotheses relevant to the problem. Teachers then researched text and electronic resources and discussed their findings with their FOP groups. Important ideas, learning issues, hypotheses and research findings were displayed on posters, and the discussions were videotaped. Each of these components of the PBL process helps reveal the sources of new ideas that emerged in participants' post-test writings.

By identifying changes in teachers' reflections on practice after analysis of the PBL teaching dilemmas, and then tracing the steps of the PBL analysis process, we were able to identify the sources of information that were most influential in shaping teacher's understanding of science teaching.

Research Question

The following question guided the collection and analysis of data:

- *In the PBL Project for Teachers, how do teachers construct science pedagogical content knowledge during PBL analysis of videotaped teaching cases?*

Design of the study

Since the FOP was designed to help develop participants' PCK, this study analyzed responses of teachers during the Focus on Practice (FOP) workshop. In the summer of 2006, 31 educators participated in the FOP workshop. Four groups of teachers were selected in order to create grade-level cohorts for the analysis of video cases. Two of the groups included secondary teachers. The other two groups each included nine elementary teachers who engaged in analysis of the same two videotaped cases (Mikeska & Stanaway, 2006). This study focused on a comparison of the two elementary groups. Data from these two groups, labeled "ElemA" and "ElemB", were analyzed for this study. Each group then took part in the analysis of two teaching dilemmas. For both dilemmas, teachers were asked to write a response to a question about teaching strategies prior to engaging in the activity. Table 1 describes the topic, the question, and the scheduling of the two groups of teachers in the dilemmas. The activity then began with some contextual information about a real teacher, her class, the lesson being taught, and a dilemma the teacher was interested in studying. The teachers then viewed a videotape of the lesson being taught. The events seen in the video were related to issues asked in the pre-test questions, so that analysis of the tape might influence participants' understanding of effective science teaching. Discussion of the teacher's dilemma followed the problem-based learning framework found in the appendix (Lundeberg, et al, 2007; McConnell, et al, in press).

Table 1
Teaching dilemmas for ElemA and ElemB groups.

Dilemma	Question	Day 1	Day 2
Circuits	What is an effective way to respond to incorrect or conflicting student ideas or widely varying data?	ElemB	ElemA
Falling Objects	How do you structure students' interactions to promote effective learning?	ElemA	ElemB

In order to understand how teachers constructed knowledge during the Focus on Practice workshop, we collected participants' written responses to the pre-test questions as an assessment of their initial ideas about teaching science. The groups discussed the dilemma after viewing the videotaped episode. This initial discussion including brainstorming of possible recommendations and questions that needed further exploration. Teachers then searched educational texts, journals, and websites to find research literature relevant to the learning issues they had identified. A second session of discussion allowed group members to share their the information they found, talk about how it related to the dilemma, and synthesize revised hypotheses and recommendations for the teacher in the teaching episode.

To assess the changes in their understanding of effective science teaching, we then administered the same questions to elicit the participants' ideas after their analysis of a teaching dilemma. Then, to infer the source of the new ideas, we traced teachers' new ideas to statements recorded during group discussions identified critical events in group discussions and research activities or to information found by the teachers during literature searches. Patterns in the activities that correspond to the emergence of new ideas were used to draw inferences about the impact of the group's analysis of teaching dilemmas in the Focus on Practice workshop.

In addition to the written pre- and post-assessments, data sources included transcripts of the groups' discussions of the dilemmas. During the discussions, the groups also maintained an artifact of their analysis in the form of posters. The posters allowed the group to record the learning issues and hypotheses identified during discussion of the dilemmas. Copies of written introductions to the cases and transcripts of the videotaped cases provide supporting evidence of the questions and contextual information provided to each group. Demographic information collected in surveys and observations of the analysis of the teaching dilemmas also contributed supporting data during the analysis and interpretation of data. The supporting data including observations about participants' interactions and their use of a variety of information sources such as the Internet, journals, and educational texts.

Analysis of the data included open coding (Strauss & Corbin, 1998) of participants' written pre- and post-dilemma responses to identify distinct pedagogical ideas in both the pre- and post-analysis writings. Coding of the pedagogical ideas included re-coding by two post-doctoral researchers to establish an inter-rater reliability of 0.92 (Lincoln & Guba, 1985). Comparison of the pre- and post-assessments revealed that participants included strategies in their post-test responses that were not found in the pre-test responses. Written records on posters and transcripts of group discussions were then coded with labels identifying their source, such as discussion of the video cases or the literature researched by group members. These coded transcripts were analyzed to find specific events and comments that appeared to contribute to the teachers' construction of new ideas. Patterns in the emergence of new ideas and their corresponding sources were displayed in case-based matrices of the various data sources (Miles & Huberman, 1994). The number of new ideas traced to different sources were also analyzed quantitatively using two-tailed T-tests.

Findings

The data analyzed in this study reveal that two primary sources of ideas contributed to the construction of teachers' pedagogical content knowledge. Teachers constructed or adopted new ideas about effective science teaching strategies that came from the ideas mentioned by their peers during group discussions, and from researching the science education literature. Both sources helped teachers construct an understanding of which pedagogical practices are best suited for teaching science content in a given context. As such, we inferred that the new ideas expressed in post-test responses represent a developing pedagogical content knowledge. In the following section, we describe patterns in the sources of information that appeared to contribute most to the development of teachers' pedagogical content knowledge.

All of the teachers in this study wrote about teaching strategies in their post-analysis writings that did not appear in their writings prior to discussion of the video-based teaching case. Many of the responses reflect very closely the comments of other group members during discussion of the facts and learning issues identified during analysis of the videotaped case. Table 2 provides representative examples of the comments from group discussions that appear to have resulted in teachers' new ideas about effective teaching strategies. Samples of a teacher's post-test responses are paired with comments made by other group members either during the initial discussion of the dilemma or when teachers shared the research they had found. Comments from group discussions were coded as "research" when the speaker was describing information found in his or her search of books, journal, or web sites. Comments made during discussion of the research results, but not describing information from a literature source, were coded as "research discussion." These comments usually included interpretation of the relationship between the research and the teaching dilemma represented in the videotaped case. The fourth example in Table 2 illustrates the research discussion comments. In the coded post-test responses, the eighteen teachers in the two groups expressed 91 new ideas. Each new idea was distinct from the ideas recorded in the pre-test responses. Of these new ideas, only eight could not be traced to a statement made during the transcribed discussions. The new ideas were traced to comments in the transcripts of the group's dilemma analysis. The ideas could be traced back to 232 different coded comments, 114 (49%) were made during group discussions that took place *before* the group members began researching relevant literature, while 48

(21%) of the comments were found in discussion *after* researching the literature. Of the 232 coded comments, 70 (30%) of the comments included descriptions of information found in the literature the teachers had researched. The participants in both groups seemed to rely much more on the discussions between group members as the primary source of new ideas rather than published research.

Table 2
Comparison of sample post-test responses to discussion comments.

Participant	New Ideas in Post-Test	Comment from Discussion
FP06-22	Teacher demo if needed	SP: If we still can't come up with one group thatis saying that we did this instead of that, then I do a classroom demonstration. We all do it together. – D
FP0-5-10	A teacher should listen well to the students, jump into discussions to repeat something said prior to get conversation going again, and then get out of the way and let them talk again.	GH: Then I found this that says the main role for the teacher is to try to understand how the children think. – R
FP05-18	You need to set the "tone" for student interactions. They need to respect each others' ideas.	KT: Well, first of all they have to accept that each student has something to contribute and all the ideas should be considered. I think that we really did see that in this tape too, where they were very respectful of each others idea, so that's important. -RD

Note: D = comment from discussion, R = literature research findings.
RD = discussion of research findings.

The trend of teachers relying more on discussion with their peers than on research as the primary source of new ideas seems clear, but in order to check for differences between the two groups and between the two dilemmas, an analysis of the data across the two sample groups and across both dilemmas was conducted. Two-tailed t-tests assuming unequal variance compared the number of new ideas traced back to each source for each group. Responses from the Circuits and Falling Objects dilemmas were also compared using t-tests. No significant differences were found between either the two sample groups or the two teaching dilemmas.

Because the two groups and the two dilemmas do not show different patterns in the responses, data from all four sessions were compiled to allow a comparison of the number of ideas traced to discussion and research sources. The tests showed the teachers constructed their new ideas from discussion with their peers more than twice as often as from information from research literature. A significantly higher number of discussion comments ($t(30) = 3.97$, $p = 0.00038$, Cohen's $d = 1.32$) led to the appearance of new ideas in post-test responses than researched information. Table 3 gives a detailed report of the results of the comparison between the two sources of new ideas.

This pattern was consistent across both groups, and in both the Circuits and Falling Objects teaching dilemmas. The only exception was a second-year kindergarten teacher, Caitlin (a pseudonym). In her post-test responses, she included seven new ideas about teaching science. These seven ideas were traced to 24 different comments, 13 (54%) were reports of research found by members of her group. The ideas were traced back to only 11 discussion comments, and eight of those were discussion of researched

Table 3
Comparison of number of new ideas traced to discussion and research.

	Mean	*SD*	t stat (*df* = 30)	Effect size *d*
Ideas traced to discussion	9.00	4.33	3.97*	1.32
Ideas traced to research	3.90	3.34		

*p < 0.001

information. Caitlin's use of research as a source of ideas is dramatically different from the other participants. Caitlin's greater reliance on research literature as a source of new ideas prompted questions about whether teachers differ in their use of discussion and research based on their years of experience. The teachers in the two groups had an average of 8.5 years of experience, including three with 27 or more years of teaching. Seven of the teachers, including Caitlin, had completed only one or two years of teaching when the summer workshop took place. Table 4 provides a comparison of the source of teachers new ideas based on experience. While Caitlin is the only teacher for whom more than half of the new ideas on her post-test were traced back to research findings, participants with less than three years experience derived new ideas from research almost three times more often than more experienced teachers ($t(9) = 2.60$, $p = 0.035$, Cohen's $d = 1.37$). The new ideas expressed by the newer teachers were also traced back to a significantly higher number of research discussion comments ($t(9) = 2.51$, $p = 0.033$, Cohen's $d = 1.28$) than the experienced teachers.

Another potentially important pattern was found when the nature of thenew ideas was analyzed qualitatively. Each group seemed to have one or two "themes" that appeared in the new ideas expressed by most of members'

Table 4
Comparison of source of ideas based on years of teaching experience.

Source of New Ideas	Teaching Experience	Mean	*SD*	*t* stat	Effect Size
Initial Discussion	1-2 years	6.29	1.98	-0.062	0.027
	> 2 years	6.36	3.38		
Research Finidings	1-2 years	6.43	4.12	2.60*	1.37
	> 2 years	2.72	1.19		
Research Discussion	1-2 years	4.71	3.20	2.51*	1.28
	> 2 years	1.36	1.86		

*p < 0.05

post-test responses for each dilemma, even though a wide range of other ideas were expressed by the group. For instance, every member of the ElemA group responded to the Circuit's dilemma post-test by writing about teacher facilitated discussion of data and experimental procedures as an effective way to deal with conflicting data and misconceptions. For three of the nine teachers in the ElemA group, this was also found in their pre-test responses. The other six had all incorporated the idea of what the group called "guided discovery" into their understanding of effective science teaching. When this concept was traced to the transcripts of the discussions, the idea of guided discovery was found in the initial discussions, the research information reported to the group, and the group's discussion of the research findings.

After the ElemB group's analysis of the Circuit's dilemma, seven of the nine members wrote about teacher questioning as an approach to the same question of dealing with misconceptions. Again, the data reveal that the topic of teacher questioning was included in both the discussions and the research findings. On the post-test for the Falling Objects dilemma in which teachers were asked how to promote student interactions, the ElemA group all wrote about understanding when to shift from teacher –led to student-led discussions, while the ElemB group wrote about setting "rules" for discussing students' ideas, including accepting different opinions and not criticizing ideas that differ from your own. Just as in the Circuits dilemma, these common "themes" were traced to both discussion comments and researched information, while other ideas not as widely seen in post-tests from the group were more likely to be traced only to discussion comments.

Discussion

In this study, we examined the sources of information during a science professional development activity in which teachers use a PBL framework to analyze a videotaped teaching episode. The data reveal that participants derived most of their new ideas from comments made by colleagues during group discussions. Educational research literature and texts were a relatively minor source of new ideas. We posit three assertions based on the data collected:

1. Teachers are more likely to adopt ideas they learn from colleagues or personal experience than from educational research.
2. Beginning teachers are more likely to construct their new ideas from education research than experienced teachers.
3. New ideas are most likely to be adopted by teachers when research findings related closely to the experiences of at least some of the group members.

Questions remain as to *why* teachers in the two groups relied so much more on discussion with their peers than on educational research as a source of ideas. The following section discusses some possible reasons for the patterns seen in the data.

Teacher Reliance on Experience

The pattern in the types of information sources from which participants derived their new ideas about science teaching suggests that PCK is strongly influenced by either a teacher's personal experiences or the experiences of colleagues. This assertion echoes Shulman's (1986) description of the development of pedagogical content knowledge. Education research literature appears to carry much less influence in shaping teachers ideas. The participants in the PBL Project rarely assimilated the ideas they found in science education texts, journals, and websites.

The data also suggest that information from research literature was contributing to certain new ideas. The new ideas or "themes" that seemed nearly universal within each group were supported by published research. However these new ideas had already been mentioned in the discussions that took place before teachers began to explore the research literature. Other concepts that were found in the literature but did not emerge in discussions were incorporated to very few of the teachers' new ideas. This pattern suggests that teachers do not assimilate ideas found in published educational research unless they are able to recognize and discuss with peers the relationship between the research and their lived experiences.

Teacher Culture and Use of Research Literature

The reliance on discussion and lack of assimilation of concepts from research may also be related to teachers' lack of experience in reading educational research literature. The participants in the PBL Project often had difficulty finding useful information from journals and text, even when project staff provided articles and texts. When participants conducted Internet searches, they usually searched general search engines, and were not very familiar with education databases. Much of the information they cited was from practitioner journals and websites, with very few articles from educational research journals. All of these patterns suggest that the teachers are not accustomed to reading educational research or implementing new ideas found in the literature. Without experience in using research literature, it is not surprising that teachers would not assimilate new ideas from the literature into their understanding of effective teaching strategies. Reading research for understanding and applying the research to a given context require practice that many of our participants lacked.

The participants also come from a culture of teacher learning that places a higher value on personal experience than on research (Stanovich & Stanovich, 2003). Teachers function in an environment in which strategies that work, either for them or for colleagues they respect and trust, are the most highly valued source of knowledge. When an activity seems to work for the teacher and her students, she is likely to continue using it and to share the activity with her peers. In her busy schedule, the teacher is not likely to spend time critically reading the findings of educational research.

Differences Between Beginning and Inexperience Teachers

Another interesting issue relates to the differences between beginning and experienced teachers. The seven participants with only one or two years of teaching experience at the start of the workshop reported new ideas that could be traced to research findings much more often than the experienced teachers. Other participants in this study had a great deal more experience upon which to draw. In some cases, the experienced teachers have already incorporated the pedagogical concepts later found in the literature. In others, experienced teachers seemed to have less faith in educational research, and found more useful information in the comments made by their peers during conversations about the teaching dilemma. In either case, the veteran teachers were clearly more likely to adopt new ideas from their colleagues.

The seven beginning teachers in the ElemA and ElemB groups derived more of their new ideas from research literature than teachers with more experience. One possible explanation for this is that teachers in the early stages of their careers are more willing or able to use published research as a tool for developing ideas about teaching science. Another more likely explanation is that teachers place more trust in their own observations and inferences as they gain experience. If this is the case, Caitlin and other beginning teachers who take part in ongoing professional development are likely to shift the focus of their learning to include more evidence from their own experiences. A longitudinal study of participants in the PBL Project may reveal that teachers' use of research literature changes over time.

Caitlin's Reliance on Literature

Even though beginning teachers' new ideas were traced back to a significantly higher number of research findings, Caitlin's case still stands out. The other six beginning teachers relied more on discussion with peers to guide their construction of new understandings about teaching science. Caitlin was unique in the degree to which she learned from the educational research literature. What could account for the differences in the way Caitlin uses the information she encountered?

One likely contributing factor is that Caitlin's mother had earned a degree in engineering before becoming a middle school science teacher. Caitlin's mother is also a participant in the PBL Project, and exhibits a strong understanding of the importance of evidence. She also is very deliberate and thoughtful in her use of educational texts to support her practice. Growing up in a household in which scientific evidence and published research were commonly used tools, it seems reasonable that Caitlin would turn to research literature as an important source of new ideas.

An even more significant factor seems to be Caitlin's individual learning style. Like younger students, teachers do not all learn the same ways. Many of the participants in the PBL Project workshops were verbal learners who naturally choose to talk about concepts with group members. Others were kinesthetic learners who elected to learn science concepts through hands-on experiences. Observations by several project planners and facilitators suggested that Caitlin's learning style was strongly based on listening to her peers and reading information from which she could construct new understandings of effective science teaching. In group discussions, she was very quiet, and facilitators usually needed to direct questions to her before she would express her opinions. Her case reminds us that as teachers of teachers, we still need to provide the resources needed to support learning for a wide range of individual needs.

The Alignment of Research and Experience

The last important pattern in data involves the consistent appearance of a common idea that appears in the post-test responses of nearly every teacher in each of the dilemmas. When research findings support a concept discussed by teachers during conversations about personal experience, nearly every teacher adopted the concept. This pattern suggests that teachers place a greater degree of trust in the research literature if they have an opportunity to relate what they have read to either their own experiences or those of colleagues within their collaborative groups. The participants in the PBL study seldom assimilated new ideas that were only found in research literature. Without some experiential knowledge that corroborates the research, most teachers, and especially the more experienced ones, are unlikely to learn concepts found in the research literature, even if the research is relevant and trustworthy.

Teachers are especially reluctant to use research publications as an important source of new ideas if the literature reflects contexts and experiences they do not perceive as similar to their own teaching situations, or if the research does not provide some practically useful strategies that can be easily incorporated in teachers' everyday practice. Stanovich and Stanovich (2003) report that teachers often find "the research literature sometimes fails to give them clear direction. They will have to fall back on their own reasoning processes as informed by their own teaching experiences" (Stanovich & Stanovich, 2003, p. 27). One approach to developing a stronger link between teachers' practice and research has been to involve teachers as contributors to the research process. Teacher research (Cochran-Smith & Lytle, 1993; Syrjala, 1996; van Zee & Roberts, 2001) and collaborative inquiry (Huffman & Kainin, 2003) are approaches to teacher professional development that have contributed to the design of the PBL Project. The teachers described in this study were only just beginning to learn about these concepts. It is possible that the participants became more comfortable reading and talking about educational research literature as they spent more time in collaborative inquiry into their own practice. Future studies related to the PBL Project will look at how teachers implement the information they find and the concepts they learn from their analysis of teaching dilemmas over a period of time.

Implications for Science Teacher Educators

Based on the findings of this study, science teacher educators need to employ strategies for professional development that have been demonstrated to be effective in changing teachers' understanding and practice. This study provides evidence that pedagogical content knowledge increases as a result of teachers' collaborative analysis of problem-based teaching cases. The discourse between participants in the PBL groups contributed the most to the construction of new ideas about science teaching strategies among the participants in this study. The findings of this study offer support for the use of collaborative inquiry in which teachers explore effective teaching strategies. Especially when working with teachers with more than two or three years of teaching experience, this study suggests that collaborative analysis based on experience is more likely to result in changes in teachers' understanding and practice than providing research literature to the teachers.

The study also suggests that beginning teachers may need more support to make collaborative analysis and group discussions more meaningful. Individuals in their first couple of years as a science teacher will benefit more than experienced teachers from texts and journal articles that illustrate the effectiveness of a given teaching strategy. Still, these teachers need an opportunity to talk about the research and how it relates to their own practice. For this reason, another important component of professional development for beginning teachers is the creation of groups that include more experienced teachers. The importance of mentors in the development of new teachers has wide support, and should be considered when designing professional development experiences. Such practices are already encouraged in much of the literature on facilitating changes in teacher practice (Loucks-Horsely, Love, Stiles, Mundry & Hewson, 2003; Roth; 2007), and this study provides additional support for the importance of collaborative analysis and discourse as an essential component of effective professional development.

The differences in the ways beginning and experienced teachers learn about new teaching strategies is very important for professional development providers to consider. This study reveals that addressing the needs of participants in their programs, and provide for the learning needs of a diverse group of teachers could significantly impact teacher learning. Demographic surveys and assessments of needs and learning styles can help planners make accommodations for the range of teachers they encounter. Planning for collaborative groups should also take into the account the specific needs of beginning and experienced teachers, included differences in the amount of time spent examining research literature and the need for experienced teachers to help younger participants relate research to the realities of classroom science teaching. Thoughtful planning of the group discussions can then help teachers make better use of research literature by providing a more explicit link between research and practice.

Teacher research and collaborative inquiry also may help teachers learn to place a greater value on published research and to use the information found in the literature more effectively. Teacher research continues to be an important part of science teacher professional development. Over time, we can hope that engaging teachers in *producing* research will result in teachers *using* more research to support their professional growth.

Science professional development that brings about changes in teacher knowledge and practice is a challenge. In order to facilitate learning among practicing teachers, we need to have a clear vision of the learning goals. We also need to understand how teachers learn, and the sources of information that are most effective in bringing about the desired changes. The findings of this study clearly indicate patterns in how teachers construct new ideas that should inform the design of professional development.

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Appendix

Summary of the Process for Analyzing PBL Dilemmas
(adapted from McConnell, et al, in press)

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