Conditions for Collaborative Knowledge Construction of Inservice Science Teachers in Problem-Based Professional Development

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Abstract

Problem-Based Learning (PBL) holds great promise as an innovative professional development (PD) model in preparing effective science teachers. However, little empirical research has been done to examine its use in the PD context. Particularly, little attention has been paid to the group collaboration process, one of the essential characteristics of PBL. In this study we examine how science teachers collaboratively construct their knowledge in a professional development seminar using a PBL approach, and explore conditions that support or hinder teachers' collaborative knowledge construction. Multiple sources of data, including video recordings, artifacts, pre-post tests and evaluations, were collected in a two-week summer professional development workshop, in which 35 science teachers participated. We employed discourse analysis and conversation analysis methods to analyze the talk in problem-based learning, and found several conditions that appeared to support collaborative knowledge construction, which included: 1) making discussion relevant to the participants; 2) challenging teachers' thinking; 3) questioning by teachers; and 4) a small number of learning issues for research. Implications for science teaching are discussed.

Conditions for Collaborative Knowledge Construction of Inservice Science Teachers in Problem-Based Professional Development

In the late 1960s, Problem-Based Learning (PBL) was introduced to medical education to replace the traditional large class lecture method with a new approach that emphasizes small group collaboration and self-directed research in solving medical problems (Barrows, 1996). About forty years after its introduction, PBL as an instructional model has gained increasing attention in various disciplines outside medical school. Allured by the great potential that PBL offers in promoting active learning, higher-order thinking, collaboration and problem solving skills, and life-long learners in professional education, we have adopted this approach in a Professional Development (PD) program for K-12 science teachers.

Because of the great variety of domains, contexts, goals and forms in which PBL is adopted, the research community has not yet achieved a universal definition for this instructional approach. Various definitions of PBL exist in literature. However, despite the differences in PBL descriptions, most researchers agree that PBL should include several characteristics: 1) student-centered learning, 2) small group collaboration, 3) self-directed study, 4) ill-structured problems, and 5) guidance of facilitators (Barrows, 1996; Savery, 2006). This study focused on one of the essential characteristics of PBL, small group collaboration. The purpose of this study was to examine how science teachers collaboratively construct their knowledge in a professional development seminar using a PBL approach, and explore conditions that support or hinder teachers' collaborative knowledge construction.

Collaborative knowledge construction has been studied under different names, such as co-construction of knowledge (Jacoby & Ochs, 1995), shared sense making (Ladewski, Krajcik, & Palincsar, 2007), co-generative dialogues and reciprocal sense making (Dillenbourg, 1999). Nonetheless, the vast majority of research on collaborative knowledge construction has been restricted in the context of Computer Supported Collaborative Learning (CSCL), often mediated by visualization tools, such as concept maps (Fischer, Bruhn, Grasel, & Mandl, 2002; C. E. Hmelo-Silver, 2003).

Collaborative learning in PBL is a form of "distributed cognition" (Salomon, 1993) in that multiple parties participate in the development of a final theory. "Collaboration means an active give-and take of ideas between persons rather than one person's passively learning from the other. Collaborative learning experiences are ones in which participants discover solutions and create knowledge together" (Damon, 1984, p. 334).

The PBL approach embeds a variety of mechanisms that are thought to enhance collaborative learning. In a PBL group discussion, collaborative knowledge construction is achieved through activating learners' prior knowledge, identifying knowledge deficits, explaining to others, reasoning with evidence, questioning each other, and solving cognitive conflicts or disagreements (Dolmans & Schmidt, 2006). However, to date, the group collaboration process in PBL is an area that has been largely neglected in the research. So, how these mechanisms actually work remains unclear. Hmelo-Silver (2004) identified five goals that PBL attempts to help learners achieve, including "1) flexible knowledge, 2) effective problem-solving skills, 3) self-directed learning skills, 4) effective collaboration skills, and 5) intrinsic motivation" (p. 235). After a thorough review of PBL research, she concluded that considerable attention has been paid to the first three goals, but little has been paid to collaboration and intrinsic motivation.

Collaborative knowledge construction in PBL is a discursive process. Glenn and associates (1999) applied ethnomethodological conversation analysis to analyze a segment of a problem-based learning (PBL) meeting in which six 2nd-year medical students discussed a clinical case guided by a faculty facilitator. In this segment, one student presented a theory to account for the patient's symptoms. Before this theory was accepted or rejected by the group, the same student presented her second theory, which received objection and laughter from the other two group members. The objection prompted the presenter to discard the second theory and return to the first. As a result, the first theory was implicitly accepted by the group. Although the two theories were presented as a result of self-directed individual learning, the treatment of the theories is an interactional, collaborative process through questioning, explaining, and arguing. The acceptance of the first theory was not because of its absolute truth but because of the group reaction that followed the second theory. Therefore, in PBL, "Theories survive or fall in a rhetorical, intersubjective, communicative context" (Glenn et al., 1999, p. 130). The study of Hmelo-Silver & Barrows (2008) revealed the similar discursive process when a hypothesis about a patient's symptom was eliminated first and then brought back and became a central hypothesis as a result of group discussion. Given the importance of discourse in PBL, it is imperative to examine conditions that lead to productive discourse.

Collaboration is also one critical feature of effective professional development programs (Roth, 2007). Because teachers are often isolated in their classrooms, collaboration provides an opportunity for teachers to encounter alternative perspectives and challenge their assumptions. Traditional "one-shot" workshop models of teacher professional development are ineffective in preparing competent science teachers (Stein, Schwan Smith, & Silver, 1999). Researchers have recognized the need for newer, more collaborative PD models that emphasize the importance of learning communities "within which teachers try new ideas, reflect on outcomes, and co-construct knowledge about teaching and learning in the context of authentic activity" (Butler, Lauscher, Jarvis-Selinger, & Beckingham, 2004, p. 436). A recent review of professional learning communities (Vescio, Ross, & Adams, 2007) also suggests that collaboration with other teachers has a positive impact on teaching practice and student learning. However, although teacher educators are increasingly adopting collaborative approaches in their PD design, little empirical research has been done to understand the learning processes in collaborative contexts.

In this study we conducted an in-depth, fine-grained analysis of group interaction processes to achieve a better understanding of the actual enactment of PBL by the participants in a collaborative group. The research question was: *What conditions might promote or hinder collaborative knowledge construction of inservice science teachers in a problem based professional development program*?

Method

Context

This study was situated in a two-week long professional development program designed to enhance science teachers' subject matter knowledge and pedagogical content knowledge through problem-based learning. This study focused on the second week of

PD called *Focus on Practice* (FOP), in which teachers developed their pedagogical content knowledge through discussing resolutions teaching dilemmas.

Participants

In the *Focus on Practice* week, 35 K-12 science teachers were divided into four groups (two elementary and two secondary) based on the grade levels they taught. Each group had 8-10 teachers and 2 facilitators, one main facilitator and one supportive facilitator. Among the 35 teachers, 9 were males and 26 were females. On average these teachers had 9 years of teaching experience and the average age was 37. Except for 1 teacher who was Native Hawaiian or other Pacific Islander, the remaining 34 teachers were Whites.

Materials

The materials included three teaching dilemmas and relevant video snippets from the TIMMS video series. The two elementary groups studied the Falling Object and Circuits dilemma. The secondary groups analyzed the Weather Map dilemma. In the Falling Object dilemma, the teacher taught first graders science process skills in a unit of falling object. Her concern was how to help students notice and resolve discrepant data. In the Circuits dilemma, 4th grade students constructed an electric circuit to provide a pathway. The teacher was struggling to help her students move from vague ideas to a more scientific understanding of circuits and pathways. In the Weather Map dilemma, eighth grade students studied a unit of Meteorology. However, the teacher observed that the students were interacting only occasionally by talking quietly or sharing maps. She wondered how she could structure the task differently to stimulate more collaboration among students.

Procedure

In the PBL process, teachers first read a text-based scenario about a teaching problem, and then discussed the problem using charts to capture their thoughts. Next, they watched video vignettes in relation to the teaching problem and continued their discussion. Thereafter, teachers conducted self-directed study on the learning issues generated in their problem discussion. Finally, teachers shared their learning in the group and made recommendations for the teaching problem. This process generally took 2-3 hours.

Data sources

The data collected for this study included video recordings of the group discussions, charts that recorded teachers' ideas emerged in discussion, pre-post tests that measured teachers' learning in each teaching dilemma, and surveys that assessed teachers' perceptions of group learning process. Video recordings and charts were the primary data sources in this study to understand teachers' collaborative knowledge construction process. We used pre-post tests and surveys as supportive data to triangulate findings from the video and chart analysis.

Data analysis

Interaction Analysis (Jordan & Henderson, 1995) provides a useful framework to guide video analysis. One group discussion was divided into several phases, including getting started, reading teaching dilemmas, problem analysis phase I, watching videos, problem analysis phase II, and sharing research findings. Next, discourse analysis and conversation analysis methods (C. E. Hmelo-Silver, 2003) were employed to analyze the talk in problem-based learning. Within each phase, two types of episodes were identified.

In the first type of episodes, several teachers co-constructed a pedagogical idea. In the second type of episodes, only one teacher contributed to an idea. For each type of episodes, we analyzed the topic of discussion, the person who initiated the topic and the person(s) who participated in the discussion and the role of facilitators. Conditions that led to rich discussion were identified.

Results

Before we report several themes that emerged in analysis that seemed to lead to active discussion, it is necessary to note that PBL group process is a very complex phenomenon, influenced by multiple factors. The model in Figure 1 describes the factors that affect group process. These factors interweave together to decide the quality of the group discussion and the nature of teacher learning.

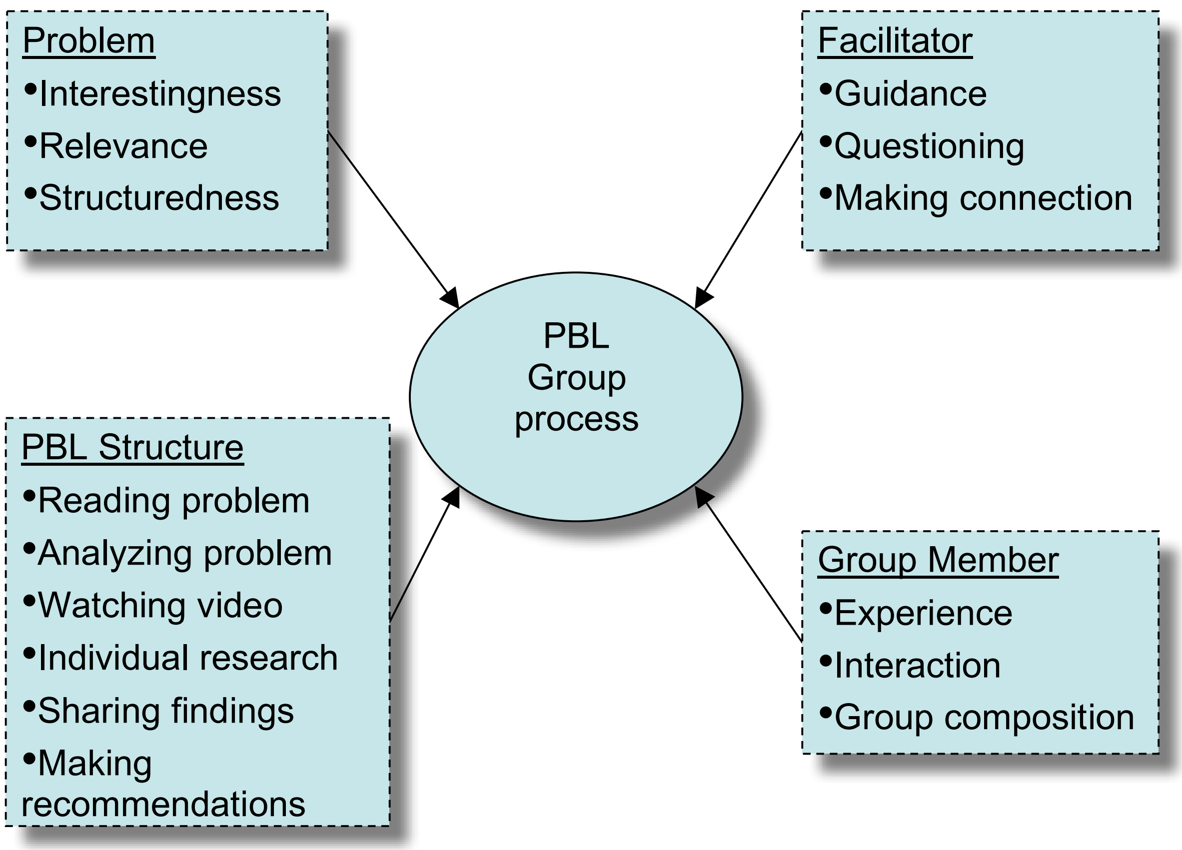

Figure 1: Factors that influences PBL group process

First, the problem itself certainly plays an important role in group discussion. An interesting, relevant, and ill-structured problem is more likely to engage participants and lead to good discussion. Second, the PBL structure affects how group process proceeds. In all group sessions, teachers read the problem, analyzed the problem, watched video vignettes, conducted individual research, shared findings and made recommendations. Particularly, in the problem analysis phase, all groups devoted substantial time to generating facts, learning issues, and hypothesis, which is unique to the PBL approach and is not very likely to happen in other types of discussion. Third, facilitators have a central influence on the group process. The moves that facilitators make and the questions that facilitators ask directly influence the direction of group discussion. Finally, the composition of group members is essential. The experience, knowledge, beliefs, motivation, and personality of group members affect how they participate in the discussion. At the same time, the interaction among group members, e.g., how familiar they are to each other, also matters a lot.

In this exploratory study, we examined six PBL group sessions, in which problems, facilitators, and group members were all different from one another. Therefore, it is difficult to make causal claims that some certain conditions always lead to the active discussion. Instead, we report patterns that we observed that are likely to lead to good discussion, which is operationalized into having multiple participants involved and multiple perspective expressed in the discussion of certain topic.

Making discussion relevant to the participants

When the discussion is relevant, group members are more likely to participate in the discussion. Both facilitators and teachers can make effort to make the discussion more relevant. First, facilitators can use several strategies to establish the relevance, including making connections to teacher's practice and playing the role of the teacher in the video.

To make the discussion relevant, facilitators asked questions to link to teachers' classroom practice. Typically, the question was expressed as: do you have this problem in your own practice? Or how do you handle this problem in your own teaching? This type of question directly links PBL discussion to teachers' practical classroom practice. It is particularly an appropriate question in a PBL session for science teachers that focused on pedagogical issues. If used in a proper context, the question is very powerful in eliciting active discussion.

The following excerpt (lines 222-226) occurred in the problem analysis phase in Circuits 1, when the group discussed how to handle students' wrong ideas. In recognition of the prevalence and difficulty of this issue in teaching practice, Stephanie, the facilitator, asked teachers how they handled the problem of dealing with students' wrong ideas in their classrooms (line 223). Ryan first explained his approach.

222. Maggie: And even if they are wrong, they need to know that, but just to say that nicely can be hard.

223. Stephanie: So, how do you handle that in the classroom? What do you do?

224. Hannah: Just tell them the answers.

225. Stephanie: That's one idea. Any others?

> 226. Ryan: Paraphrase what they say and then ask the other student, is that the idea that we're talking? And then that's a real teachable moment. If another student comes up with the same concept which is totally off base, then you can just talk about the idea and give them the correct answer and then go back to the original student and ask them, you know, does that help answer the question to get you more on track? Because you don't want to ever discourage a student from talking. You always want to be positive that they're actually contributing to the class.
>
> [Circuits 1]

After line 226, other teachers continued to offer their ideas on dealing with students' wrong ideas, which included guiding students to get the correct answer, asking the question again, providing hints, asking peers to help out, and taking a timeout and challenging students to prove their theory. As a result, Stephanie's question of linking to classroom practice evoked a rich discussion and elicited multiple perspectives on the practical teaching issue.

Role play is another strategy for creating relevance. The irrelevant, distant, unknown teacher's practice in the TIMSS video was made relevant by playing the role of the teacher in the video. Role play also makes the problem being discussed more realistic and relevant to teachers, thus making the discussion more engaging. For example, in Weather Map 1, the facilitator, Presley, played the role of the teacher in the TIMSS video that teachers watched.

> 121. Presley: Ok, today, I'm gonna be the teacher, ok? I've come to you, you're my supportive group. It's February, and I'm back again with another problem. This time, my unit very appropriately is on weather, ok, so, weather today. And, I have

some problems with the unit that I'm doing. My intentions were one thing, but it's not happening, so I need your help. What I want to do is pass out the sheet I prepared for you, and then we'll look at the video after that, Pretty much like we did yesterday, I have the topic "weather maps," I have set the context for you. [Weather Map 1]

Group members can also make the discussion more relevant by situating themselves into the discussion. For example, in at the start of the Circuits 1 session, teachers were not very engaged in the discussion. The discourse pattern is that facilitators asked a question and teachers responded to it, without building on each other's idea. The lack of engagement was evident when the facilitator told the group:

> 117. Stephanie: … Folks you've got to wake up or I'm putting you into small groups and you're going to have to really start thinking and working. So slap it up and let's go, ok? [Circuits 1]

It appears that there was a turning point in the discussion when the group was co-constructing a hypothesis about student responsibility leading to scientific understanding. After the facilitator prompted the group to develop the rationale for the statement by generating the "because" part, Elena shifted the direction of the discussion to teacher's responsibility. It is interesting to note the word "us" she used. She did not say it has to do with teachers. The usage of "us" indicated Elena placed herself into the discussion. It is the first time that the group used this word in the discussion. The earlier discussion seemed to be about the remote teacher. Then Ryan picked up the usage of "we" in making his point that teachers play a central role in student's understanding. Next, Maggie continued to use the term “us”. Her statement “Kind of like being woken up right now” indicated that the group’s engagement was enhanced.

130. Stephanie: … So, we have if students take more responsible, more responsibility for their learning and learn to think critically, then they will move towards science understanding because.

131. Elena: It has to do with us, I mean because they can't get that on their own.

132. Ryan: We have to be,

133. Elena: Because we,

134. Ryan: A firm foundation from what we are trying to give them. I mean it has to come from us.

135. Maggie: Yeah but aren't they going to be more open or more receptive to the receiving that information or discussion from us. Kind of like being woken up right now, you know …

136. Stephanie: That's a great question, hold onto that thought, hold onto that thought. Did we, did we get the “because” part down yet? [Circuits 1]

Afterwards, the group continued the discussion on several different topics. Because the increased engagement level, the facilitator praised the group.

251. Stephanie: We are a one dynamic group, don't mess with us.

252. Bella: Are we still number one?

253. Stephanie: We are number one. Is that important to you? Yeah, you're number one in my book. [Circuits 1]

In discussion, if teachers shared their teaching story, it is likely to lead to active discussion. For example, in Falling Object 1, Elise shared her experience of dealing with students' conflict idea. Her story led more discussion on this topic.

> 165. Elise: Normally when my kids [unintelligible], we've all done the same, but there's different view points, but there's different to results. I start with what could we've done differently, where could they have been an error and where could there have been different, because somebody and usually the kid who come up with maybe we didn't measure the water quite the same, maybe we didn't time with the same way for everyone we're doing. And we still can't quite come up with a one group that is drastically different saying that we did this instead of that, then I do a classroom demonstration, we do it altogether. So, we're doing drop it once and all 17-25 eyes are looking at same thing. [Falling Object 1]

Challenging teachers' thinking

When the facilitators tried to identify holes in teachers' thinking and asked questions to challenge them, it is likely to trigger rich discussion. The following lines 697-702 were located in the sharing research phase in Circuits 1, when the group discussed how to deal with students' conflicting ideas. Both Bella and Isabella suggested retesting student ideas to solve the problem. Stephanie challenged this idea by asking them if students will remain engaged if they keep retesting their ideas (line 699). She then rephrased her question into how teachers can help students engaged in testing their ideas. In response to Stephanie's challenge, Isabella developed a solution by having students test each other's idea (line 700), and Elena suggested taking pieces from student ideas and putting them all together (line 702). Afterwards, Stephanie reconceptualized their idea into teacher choice, which led to more discussion on this topic. In this excerpt, retesting student ideas is one of the possible solutions to the problem of students having conflicting ideas. For this solution, Stephanie recognized one potential problem that students may lose motivation when they have to retest their ideas again and again. Therefore, she raised the question to the teachers, which elicited more thoughtful ideas than the original approach. As a result, the challenging question deepened teachers' thinking and took their thoughts to another level.

> 697. Bella: Well, what if you let them retest then, all had these ideas, how about if everybody goes back and retests some of these hypothesis.
>
> 698. Isabella: Devising experiences and experiments, hands-on experiences where they had the opportunity to test and see these were valuable observations and we might end up going back and revisiting things all the time.
>
> 699. Stephanie: Do you think students will remain engaged if they're redoing and redoing and redoing? How as a teacher are you going to keep students engaged on the idea about testing their own ideas?
>
> 700. Isabella: Could you have them test each other's idea? Or once you come to a conclusion, teach the class and see, present to the class.
>
> 701. Stephanie: Ok.
>
> 702. Elena: Or somehow take bits from each thing the kid said and put it all together. This is what we've done, you know what, this is what we've come to as a class. [Circuits 1]

Questioning by teachers

Interestingly, in almost each group discussion, group members played different roles. These roles were roughly categorized into three types: 1) questioner, 2) explainer, and 3) bystander. Having one or more questioners in the group appeared to be beneficial for collaborative knowledge construction. Questioning by group members helped initiate a new discussion topic and maintained active discussion.

For example, in excerpt (lines 520-522) from the sharing research phase in Weather Map 2, Ivy raised a question of for how long a teacher should keep students in one group. Presley did not answer the question directly. Instead, she paraphrased the question and threw it back to the group. In response to Presley's question, Callie told an elaborated story about what happened in her school regarding grouping students. Subsequently, Leah also described her experience with heterogeneously mixed groups. Using the question raised by teachers, Presley successfully elicited multiple responses from the group and placed learning responsibility on teachers.

> 520. Ivy: We, Leah and I had a question and probably this would be to the whole group is a lot of times when students come in to either sixth, seventh, or eighth grade, they come in with buddies and problems kids sometimes get, put in the same classes and we have a tendency of the like every six to twelve weeks to shift the groupings within the classes and are wondering whether or not that really is such a good idea because what happens if change the group dynamics, every single six weeks.
>
> 521. <u>Presley</u>: <u>Did anyone run across that, the idea of keeping groups together for a long time versus changing often</u>?

522. Callie: We have this issue at our building. I mean again our classes change every sixth week. … [Weather map 2]

A small number of learning issues for research

This condition mainly affected the research sharing phase. During the problem analysis, teachers typically generated a variety of learning issues. It was important to consolidate learning issues and narrow down to a small number, so that two or more teachers can study the same issue.

The post-test responses in Weather Map 2 were much more convergent than other groups. Teachers mentioned similar ideas in their post tests. Analysis of the group discussion shows that teachers generated multiple responses during the discussion, as shown below.

Learning issues generated in discussion in Weather Map 2
What is the prior knowledge of transient Students?
How does the teacher access prior knowledge in a short time?
How have transient students affected the "tone" of classroom?
How do you make group work a group task?
What kind of roles should the Ss in the group play?
Are students arranged so that they CAN pay attention?
Directions unclear/incomplete?
Is it important to include examples of what they are to do?
How to establish a comfortable environment in which students can ask questions
How to manage class?
Ways to check for understanding
Tie in to real world (regional) map

However, they did not study all of the learning issues. Instead, they prioritized and studied three learning issues. A common research topic allowed teachers to connect to each other's findings.

Effectiveness of group work
Ways for checking for understanding
Designing motivating task

When the conditions mentioned above were present, teachers were more likely to co-construct a shared understanding about a pedagogical issue. That is, several teachers were involved in the discussion of a specific topic. They built on each other's idea. They provided their own examples to support a point offered by other teachers. They questioned one another to clarify meaning and challenge one another's assumptions. They demonstrated signs of engagement, such as different speakers trying to voice their opinion simultaneously. Arguments and counterarguments were raised. Various aspects of an idea were discussed. There were multiple exchanges among several speakers, rather than one-shot exchange between a facilitator and a teacher. As a result, teachers' pedagogical understanding was deepened. On the other hand, absence of these conditions seemed to inhibit collaborative knowledge construction. That is, when there was a lack of clear focus, or the topic is irrelevant to teachers' classroom practice, or teachers research on a wide range of learning issues, the discussion tended to be fragmented and disconnected. There were frequent shifts from one topic to another, without a thorough discussion. One-shot exchange was more likely to occur, and the collaborative construction of knowledge was interrupted.

Discussion

Fischer, Bruhn, Grasel, & Mandl (2002) described four processes of collaborative knowledge construction: 1) externalizing task-relevant knowledge; 2) eliciting task-relevant knowledge, 3) building consensus through solving conflicts; and 4) building consensus through integrating different perspectives. The six conditions described above stimulate the four processes. Questioning by facilitators and by group members helped teachers externalize and elicit task-relevant knowledge. A clear focus for discussion and a small number of learning issues for research enabled teachers to build consensus through integrating different perspectives. A controversial topic favored consensus building through solving conflicts. A relevant discussion topic helped teachers externalize task relevant knowledge and achieve consensus through integrating different perspectives.

Problem-Based Learning holds great promise as an innovative professional development model in preparing effective science teachers. However, little empirical research has been done to examine its use in the PD context. Therefore, evidence on how PBL can be implemented in science teacher PD program is greatly needed to help teacher educators make informed decisions in adapting PBL to their specific contexts, otherwise, as Hmelo-Silver (2004) stated, “it would be naïve to believe that the medical school model of PBL could be imported into other settings without considering how to adapt it to the local context, goals, and developmental level of learners” (p. 260). This study sheds light on critical conditions that promote collaborative knowledge construction, one of the essential characteristics of PBL. The findings also have implications for design of collaborative learning environments in other contexts.

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