

Teachers as Expert Learners and Fellow Travelers A Review of Professional Development Practices for Problem-Based Learning

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I'm not a teacher: only a fellow traveler of whom you asked the way. I pointed ahead—ahead of myself as well as you.

—George Bernard Shaw

George Bernard Shaw's words are an apt description of the teacher's role in problem-based learning (PBL). The label of "teacher" is, in fact, something of a misnomer for the PBL practitioner. Rather than acting as a source of content knowledge, PBL educators are lead learners, demonstrating learning to students through their own authentic inquiry (Hmelo-Silver, 2004). Truly, PBL educators and students travel a road together that often leads them into uncharted territories.

There is a nationwide call for inquiry-based pedagogies such as PBL within the current context of educational reform. In response to this call, the Partnership for 21st Century Skills (n.d.) offers a framework for K-12 educational policy and instructional design in its statement, "Within the context of core knowledge instruction, students must also learn the essential skills for success in today's world, such as critical thinking, problem solving, communication" (p. 1). Despite the use of the term "21st century" to describe these skills, the societal need for such skills is anything but new. The centrality of critical thinking and problem solving to society is evidenced in technological innovations throughout history, ranging from

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the development of simple tools to modern medical advancements, such as the invention of vaccines (Rotherham & Willingham, 2009).

The current focus on educational reforms centered on 21st century skills constitutes a call for more intentional teaching of these skills within our nation's schools. Admittedly, some rhetoric surrounding 21st century skills implies that content knowledge is obsolete and that "ways of knowing information are now much more important than information itself" (Rotherham & Willingham, 2009, p. 16). The real challenge to educational reform, however, is to honor the interconnection between content knowledge and 21st century skill application and to conceive of ways to teach both in a manner that will improve student learning.

For the purposes of this review, therefore, the National Research Council's (NRC, 2012) conceptualization of 21st century skills, which acknowledges the central role of content knowledge, will be adopted. The NRC equates these 21st century skills with "deeper learning" (p. 21), or the ability to apply learned concepts to new situations, and contends that our nation's K-12 schools must rise to the challenge of teaching core subjects in conjunction with problem solving, collaboration, critical thinking, and communication.

PBL is an instructional strategy that has the potential to meet the challenges of teaching these skills, along with core subject matter, while promoting the transfer of theoretical knowledge to practical application (NRC, 2012). It is important to recognize, however, that the instructional strategies associated with PBL place new demands on teachers for which they may not be prepared (Rogers, Cross, Gresalfi, Trauth-Nare, & Buck, 2009). To effectively translate the benefits of PBL pedagogy into the classroom, teachers will need support, including carefully designed professional development opportunities, from administrators (NRC, 2012).

Since its inception in the 1970s in the field of medical education, PBL has replaced or supplemented lecture-based instruction in nursing education, schools of engineering, and, most recently, in K-12 schools (Hmelo-Silver, 2004). PBL is a learner-centered pedagogical approach that integrates the following features: (a) a semi-structured problem with real-world context; (b) student-conducted research; (c) student application of theory to practice in the process of developing a solution; (d) small-group collaboration; (e) teacher as tutor or facilitator; and (f) student responsibility for learning (Hmelo-Silver, 2004; Savery, 2006). These features of PBL align with the philosophical underpinnings of constructivist learning theory, including its focus on learning in context, challenging learners to resolve cognitive puzzles, and socially negotiating knowledge acquisition (Savery & Duffy, 1996). The constructivist framework provides the theoretical basis for a variety of other peda-

gogical strategies such as project-based learning and inquiry learning, and, although these approaches encompass varying combinations of the components of PBL, they are often included under the PBL umbrella in educational practice and research (Savery, 2006).

There is little research, however, on PBL and student outcomes in K-12 settings (Hmelo-Silver, 2004; NRC, 2012). Savery (2006) noted that, even in post-secondary settings where PBL has a long history, there are significant gaps in research in regard to the effectiveness of PBL. Strobel and van Barneveld (2009) conducted a meta-synthesis of eight meta-analyses performed from 1993 to 2005 that compared PBL with traditional classroom strategies in post-secondary education. These researchers found that PBL strategies were superior to traditional classroom instruction in terms of long-term retention, skill development, and teacher and student satisfaction. Interestingly, traditional classroom practices resulted in better outcomes for tasks that require short-term retention, such as standardized tests. Strobel and van Barneveld concluded that additional research that focuses on effective supports for PBL, particularly in its K-12 applications, is needed.

The adaptation of PBL for K-12 educational settings is a complex undertaking (Savery, 2006). Teachers and administrators who wish to implement PBL in classrooms face daunting challenges presented by state-mandated curricula, standardized assessment mandates, and the rigid separation of subjects within the school day (Asghar, Ellington, Rice, Johnson, & Prime, 2012). In addition to the need to overcome these structural barriers, teacher practice must accommodate student-guided learning, open-ended problem solving, and the teacher-as-facilitator model that is central to PBL (Hmelo-Silver, 2004). This departure from traditional classroom practices suggests that teacher learning and change is central to successful implementation of PBL as is support in overcoming the structural challenges that exist in K-12 schools.

Effective professional development programs allow teachers to investigate an area of practice, adopt new ideas in regard to theory and pedagogy, and implement these new ideas in the classroom in a context of reflection and support (Bell & Gilbert, 1996). Professional development programs for PBL must specifically address the complexity of PBL as a teaching strategy, as “having good problems is a necessary but not sufficient condition for effective PBL” (Hmelo-Silver, 2004, p. 244). To effectively implement PBL, teachers must learn to act as facilitators, allowing students to direct their own learning by working with open-ended problems in collaborative environments (Savery, 2006). This facilitator role requires the teacher to act not as a content expert but rather as an “expert learner, able to model good strategies for learning and thinking”

(Hmelo-Silver, 2004, p. 245). The PBL teacher models problem solving, uses guiding questions to facilitate group work, and provides progressively less scaffolding as students become more proficient in problem solving (Hmelo-Silver, 2004). The effective PBL practitioner, therefore, acts primarily as a model learner and employs a flexible set of questioning skills tailored to learner ability.

While PBL poses unique pedagogical challenges to K-12 teachers, professional development activities that incorporate recognized elements of effective professional development can enhance the likelihood of classroom implementation. Because, however, PBL practices are a departure from the traditional pedagogies around which school structure is designed, professional development programs also must attend to the specific challenges that school structures and policy requirements pose for teachers. This review will provide an examination of empirical evidence on the structural elements of professional development for K-12 educators and associated outcomes as a means to identify elements of professional development that promote PBL implementation. The review concludes with a discussion of research and policy implications.

Conceptual Framework

There is a lack of consistency in the manner in which professional development programs are structured and studied, which creates a challenge in assessing the quality of programs. To address the need for structure, Desimone (2009) offered a conceptual framework in regard to the characteristics of successful professional development programs. This framework reflects researcher consensus on key elements of professional development and draws on empirical evidence from the professional development field and from a national sample of over 1,000 teachers. These data sources yielded five key features of effective professional development programs: (a) content focus, (b) active learning, (c) coherence, (d) duration, and (e) collective participation (Desimone, 2009; Garet, Porter, Desimone, Birman, & Yoon, 2001).

Further, Desimone (2009) proposed that the extent to which those features are present in a professional development program correlate with the following outcomes: (a) change in teacher beliefs and knowledge, (b) change in practice or implementation of new pedagogies, and (c) student learning outcomes. Desimone identified a wealth of empirical evidence that supports the relationship between the presence of the five key features of effective professional development and the outcomes of professional development that support this framework. Using Desimone's framework, this review will present an analysis of studies of PBL professional development.

Methods

For this study, the author examined research conducted during the past ten years on professional development for K-12 teachers in PBL. Strobel and Van Barneveld's (2009) findings on the lack of a strong research base for PBL effectiveness in K-12 provide the context for the review of research. There is a corresponding paucity of research on professional development programs in this area, and many studies in this review include PBL as one of several concurrent research foci. The body of data consists of empirical studies reported in peer-reviewed journal articles between 2004 and 2012, although two studies presented at conferences of the American Educational Research Association are included due to the overall scarcity of research in this field. Based on the interdisciplinary nature of PBL, studies in all subject areas in K-12 were included in the search. A number of the studies focus on science, technology, engineering, and math (STEM), and one focuses on PBL and General Educational Development Diploma (GED) acquisition for older teens.

A systematic search of databases, including ERIC, Academic Search Complete, the ProQuest Research Library, Google Scholar, and OhioLINK Electronic Journal Center, was conducted to identify literature on professional development in PBL for K-12 teachers. Searches were conducted using various combinations of the terms "problem-based learning," "project-based learning," "professional development," "teacher education," "teacher learning," "21st century skills," "K-12," "elementary," "middle school," "high school," and "secondary education." The reference list of each article identified was examined to locate additional studies.

As Savery (2006) noted, the PBL label is frequently applied to programs that fail to incorporate all elements of PBL. Therefore, the author sought to capture studies that incorporate the collaborative, hands-on, student-led inquiry nature of PBL and included research that designates programs as either PBL or as project-based learning. The studies included focus on K-12 teacher professional development that emphasizes PBL or project-based learning. Only articles that reflect empirical research were included. Studies that focus on professional development for post-secondary teachers and studies that focus on learning by inquiry that did not incorporate significant elements of PBL were excluded. These criteria were applied to the abstract or introduction of each article, and the full article was reviewed, as needed, to determine inclusion status. A total of 16 pieces of literature met these inclusion criteria.

Several of the studies in this review lack complete methodological or program descriptions, perhaps because PBL was one of several research foci. These studies were included, however, to create a holistic picture

of the existing research base on K-12 PBL professional development. For example, one study that focused on pedagogical approaches to mathematical problem solving, but did not explicitly identify PBL as a program component, was included (Anderson & Hoffmeister, 2008). Despite the fact that the researchers did not specify PBL as a focus of the professional development experience, this study was included in the review because it contained significant elements of PBL, including collaboration, the integration of theory and practice, and focus on the role of the teacher. Only two studies (Fallik, Eylon, & Rosenfeld, 2008; Ravitz, Hixson, English, & Mergendoller, 2012) achieved quasi-experimental design by incorporating control groups. The remaining studies were non-experimental in nature and combined qualitative and quantitative data, with many of the studies focused on small cohorts of teachers.

Review of Professional Development Programs for Problem-based Learning in K-12

To discern how PBL professional development programs' structures and outcomes are aligned with the elements of effective professional development and how programs support PBL implementation, the results of this literature review are organized using Desimone's (2009) framework for effective professional development. First, an analysis of the five critical features represented by each professional development program is offered. Next, the study findings are examined in terms of outcomes, using the themes of change in teacher knowledge and beliefs, classroom implementation of PBL, and student outcomes; an examination of barriers to implementation and how they are addressed in professional development programs is also conducted.

Critical Features

Creating and providing professional development programs for teachers is a complex task. Program development and evaluation of professional development can be especially daunting when introducing new and interdisciplinary instructional models that may require significant changes in classroom practice (Asghar et al., 2012; Desimone, 2009). Research reveals five features of professional development programs that facilitate teacher change in beliefs and classroom practices: content focus, active learning, duration, collective participation, and coherence (Desimone, 2009). Table 1 provides an overview of the professional de-

velopment programs in the studies reviewed, along with an assessment of critical features present in each program.

Content focus. Hmelo-Silver (2004) reported that PBL places significant demands on teachers to act as facilitators, or expert learners, rather than as content experts. This presents a challenge to professional development designers to encourage teachers to reevaluate their pedagogical roles in the classroom. Desimone (2009) described content focus as subject knowledge linked with pedagogical knowledge. While most programs focused on subject content knowledge, and some allowed teachers to develop curricular units, the majority of the programs included in this review lacked an explicit description of the pedagogical demands of the facilitator role and provided a limited description of the pedagogical strategies taught.

Active learning. A focus on active learning methods, such as observations, discussion, and hands-on activities, is a characteristic of effective professional development programs (Desimone, 2009). Of the studies that described active learning as a part of the professional development program, several described active learning that did not engage teachers in PBL but, rather, in methods such as collaborative inquiry (Goodnough & Nolan, 2008), observation (Kanter & Konstantopoulos, 2010), group discussion (Anderson & Hoffmeister, 2008), or an interactive cycle of planning, teaching, and reflecting (Toolin, 2004).

Duration. The changes in practice necessary to implement PBL in the K-12 classroom can be a challenge to both new and experienced teachers as they seek to define and refine their teaching practices (Ravitz et al., 2012; Toolin, 2004). Desimone (2009) identified the duration and intensity of professional development as a key factor in meeting such challenges. In general, a minimum of 20 hours of professional development activities is required for effective teacher change. These 20 hours are effective when either spread over a period of months or occurring in a condensed workshop format with follow-up in the subsequent months. Of the 16 programs reviewed, 14 involved engaging teachers for at least this amount of time.

Collective participation. A key theme among the studies reviewed is the need for ongoing, sustained support as a component of PBL professional development programs. This aligns with Desimone's (2009) collective participation criterion. Collective participation indicates that a cohort of teachers from a school or district attend the professional development experience to facilitate "interaction and discourse" (Desimone, 2009, p. 184) on an ongoing basis. All but two studies (Fallik, Eylon, & Rosenfeld, 2008; Zhang, Parker, Eberhardt, & Pallacqua, 2011) provided a description of programs in which the cohort of teachers in

Table 1
Summary of PBL Professional Development Programs Studied and Assessment of Desimone's (2009) Critical Factors

Authors	Description of Professional Development Program	Content Focus	Active Learning	Coherence	Dura-tion	Collective Participation
Anderson and Hoffmeister (2008)	Graduate-level summer course for mathematics teachers (majority middle school). Focus on teaching by problem solving, student thinking, and discussing research.	Yes	Yes	Yes	Yes	Yes
Asghar, Ellington, Rice, Johnson, and Prime (2012)	Interdisciplinary STEM workshop (five days over five months). Objectives were to enhance content knowledge; enhance approaches to PBL and overcome student and teacher resistance to PBL use; support PBL integration in classroom; and create problems for secondary classrooms. Used Illinois Mathematics and Science Academy (IMSA) professional development model.	Yes	Yes	Yes	Yes	Insufficient description
Boulden (2008)	Advancing Young Adult Literacy (AYAL) is a program for teachers who work to prepare 16-24-year-olds for the GED. It combines Youth Cultural Competency (YCC), Case Management (CM), and PBL. Teachers were trained in implementation and provided with ongoing support via site visits and follow-up meetings.	No	Insufficient description	Yes	Yes	Yes

Table 1 (continued)

Authors	Description of Professional Development Program	Content Focus	Active Learning	Coherence	Dura-tion	Collective Participation
Bradley-Levine, Berghoff, Seybold, Sever, Blackwell, and Smiley (2010)	Three-day summer institute for 250 middle and high school teachers and administrators. Participants collaborated to create PBL activities and assessments.	Insufficient description	Insufficient description	Yes	Yes	Yes
Fallik, Eylon, and Rosenfeld (2008)	Long-term continuous professional development (CPD). Two frameworks were studied: (a) 21-28 hours of in-service workshops for middle school science and technology teachers focused on experiential learning and modeling; and (b) teaching teams of teachers with PBL experience composed of 28-56-hour workshops, depending on needs of the teachers. Focused on planning and enacting PBL in classroom, assisting students, and addressing administrative issues with PBL implementation.	Yes	Yes	Yes	Yes	Insufficient description
Foutz, Navarro, Hill, Thompson, Miller, and Riddleberger (2011)	Five-day summer workshop (follow-up is not described) for middle and high school teachers. Collaboration with University of Georgia to integrate math and science curriculum. Focused on introducing real world context through PBL; integrating content instruction between math and science; helping teachers understand interdisciplinary nature of math and science. Workshop activities organized around an agricultural engineering PBL problem.	Yes	Yes	Yes	Yes	Yes

Table 1 (continued)

Authors	Description of Professional Development Program	Content Focus	Active Learning	Coherence	Dura-tion	Collective Participation
Goodnough and Nolan (2008)	Collaborative inquiry (CI) group formed to explore pedagogical content knowledge that focused on PBL in the context of science education. Eight-month program that involved elementary teachers, a program specialist, and a researcher/teacher educator. The group met for four days, six hours/day over four months to explore PBL and develop a model for implementation.	Yes	Yes	Yes	Yes	Yes
Kanter and Konstantopoulos (2010)	Graduate-level course for urban middle school science teachers. Students met three hours/week for ten weeks. Focused on student thought and big ideas; content lectures or labs; and analyses of student understandings of big ideas.	Yes	No	Yes	Yes	Yes
Lehman, George, Buchanan, and Rush (2006)	Three-week, school-based summer institute with follow-up sessions for grade 5-9 teachers. Project INSITE (Institute for Science and Technology) focused on pedagogical and philosophical supports for science teaching; strategies to enhance student learning; role of teacher and student in using information technologies to enhance creativity and critical thinking.	Yes	Yes	Yes	Yes	Yes

Table 1 (continued)

Authors	Description of Professional Development Program	Content Focus	Active Learning	Coherence	Dura-tion	Collective Participation
Paik, Zhan, Lunderberg, Eberhardt, Shin, and Zhang (2011)	Two-week workshop for K-12 science teachers as part of a five-year PBL professional development project funded by the National Science Foundation (NSF) to improve content and pedagogical knowledge. The workshop focused on content, curricular development, and practice. Participants engaged in PBL and planned units to correspond with state standards.	Yes	Yes	Yes	Yes	Yes
Pederson, Arslanyilmaz, and Williams (2007)	Informal, professional development for utilizing educative materials embedded within the PBL online program (Alien Rescue). Intent of educative components of curricular materials is to “address teacher learning as well as student learning” (Pederson et al., 2007, p. 246). Teachers received information about PBL in a just-in-time fashion. Half of the teachers had attended PBL professional development previously.	Yes	No	No	No	Yes
Ravitz, Hixson, English, and Mergendoller (2012)	Week-long summer workshop to develop PBL lessons that emphasized 21st century skills. Control group had no PBL professional development.	Insufficient	Insufficient	description	Yes	Yes

Table 1 (continued)

Authors	Description of Professional Development Program	Content Focus	Active Learning	Coherence	Dura-tion	Collective Participation
Rogers, Cross, Gresalfi, Trauth-Nare, and Buck (2010)	Of the three ninth-grade math and science teachers studied, two had engaged in a summer workshop based on a technology-oriented PBL program. The third was a new teacher who had PBL exposure in his teacher education program but did not attend the summer workshop. Workshop focused on an online project building system, working collaboratively to complete PBL project, and pedagogical implementation of PBL. A coach from the technology program provider was available during the year.	Yes	Yes	No	Yes	Yes
Toolin (2004)	Middle and high school science teachers in New York City participated in a Community of Science Educators (COSE) to provide staff development for project-based learning. Teachers attended summer and periodic school-year workshops focused on collaboration and enhancing knowledge related to project-based learning.	In sufficient description	Yes	No	Yes	Yes

Table 1 (continued)

Authors	Description of Professional Development Program	Content Focus	Active Learning	Coherence	Dura-tion	Collective Participation
Walker, Recker, Robertshaw, Osen, and Leary (2011)	Two professional development formats that utilized a web-based program, Instructional Architect, were studied: (a) PBL taught concurrently with technology in two workshops held over three months focusing on using technology resources to create student activities in a PBL context; and (b) technology skills, with a focus on accessing and understanding resources, were taught before PBL pedagogical skills. Participant grade level and subject focus were not specified.	Yes	Yes	No	Yes	Yes
Zhang, Parker, Eberhardt, and Pallacqua (2011)	The kindergarten teacher study subject attended a two-week summer workshop and participated in an action research project. The workshop focused on collaborative science problem solving and discussion of pedagogical strategies; content understanding; curricular design; and designing a research program for an identified teaching challenge.	Yes	Yes	Yes	Yes	Yes

the professional development program was drawn from a single school or district.

Coherence. To be most effective, a professional development program must include concepts and practices that are consistent with teacher beliefs and in alignment with policies that govern school structure and curricular content (Desimone, 2009). Professional development programs that introduce substantial shifts in teacher practice should, therefore, introduce material in the context of district or school policies and include implementation support for teachers as they return to classrooms (Darling-Hammond & McLaughlin, 1995). While most programs contained evidence of alignment with teacher beliefs, only four of the programs explicitly addressed the effect of structural factors, such as curricular mandates and standardized testing (Asghar et al., 2012; Lehman, George, Buchanan, & Rush, 2006; Paik et al., 2011; Pederson, Arslanyilmaz, & Williams, 2007).

Discussion of critical features. The studies reviewed incorporated Desimone's five criteria in various combinations. Where program descriptions were available, all but two of the programs incorporated at least three of the five components, and six programs were described as effectively incorporating all of the five key features (Table 1). Although nearly all the programs drew teachers from a single school or district, the most commonly omitted feature was that of coherence. As noted above, the majority of the programs did not address the structural challenges that teachers face in implementing PBL in the school setting, an omission that almost certainly affects teachers' abilities to adapt this pedagogy to the school and classroom context. This finding suggests that particular attention should be paid to the coherence factor in professional development design. By attending not only to teachers' beliefs, but also to the contexts in which teachers practice, professional development programs may be able to support teachers more effectively in PBL implementation.

Professional Development Outcomes

In regard to the active learning component of Desimone's (2009) conceptual framework for studying professional development, she posits that the importance of the five critical features lies in the positive correlation between their presence and positive outcomes of professional development, including change in teacher practice and, ultimately, student achievement. The following sections present the aftereffects of the programs studied, using the themes of change in teacher knowledge and beliefs, classroom implementation of PBL, and student outcomes.

Change in teacher knowledge and beliefs. Ertmer (1999) noted that

second-order barriers to teacher change, those rooted in “teachers’ beliefs about teacher-student roles as well as their traditional classroom practices” (p. 51), can be a challenge to implementing new teaching methods. Accomplishing change that overcomes these second-order barriers is a complex task for professional development providers and one that requires close attention to Desimone’s (2009) critical features of professional development.

The authors of two studies suggested that explicit separation of professional development activities oriented toward developing technical skills from those focused on pedagogy improved teacher understanding of PBL and its implementation in the classroom (Rogers et al., 2010; Walker, Recker, Robertshaw, Osen, & Leary, 2011). Walker et al. studied a two-year professional development program that was delivered in two iterations: one with technology usage instruction integrated with PBL, and the other with technology content presented prior to PBL content. The findings indicated that those who received PBL training separately from technology training implemented PBL at higher rates. Further evidence that integration of technology and pedagogical content may result in limited acquisition of pedagogical understanding and difficulties with PBL implementation was provided in Rogers et al.’s case study. The results of the study of three teachers who participated in a summer professional development program that focused on a technology-based PBL program indicated that the professional development workshop lacked sufficient pedagogical content to support educators in making cognitive shifts in their approach to subject matter and pedagogy. Rogers et al. concluded that there was a need for extended professional development to support these shifts in knowledge.

Two studies found that participants had difficulty with synthesizing content and pedagogical knowledge (Anderson & Hoffmeister, 2007; Asghar et al., 2012). The 19 middle school math teachers who attended a summer graduate course, which was the focus of Anderson and Hoffmeister’s study, reported a lack of clarity in regard to the distinction between procedural and conceptual learning introduced in the course. The results of a survey indicated that teachers had difficulty with integrating content knowledge and practice after the course, although 89% of the teachers reported moving toward a more conceptual understanding of content (Anderson & Hoffmeister, 2007).

The need for attention to the synthesis of content and pedagogy also noted in Asghar et al.’s (2012) study of an interdisciplinary PBL professional development program for teachers in STEM subjects. The professional development program, based upon the Illinois Mathematics and Science Academy (IMSA) model, focused on experiential learning in PBL, engag-

ing in problem design, correlating learning with standards, and developing assessments. The teachers in this program experienced the content and pedagogical presentations as separate bases of knowledge and had difficulty with integrating the two in practice. Because both of these professional development programs incorporated all five critical features of effective professional development, the findings suggest that the specific demands of PBL pedagogy require additional PBL modeling and more emphasis on active participation, specifically in the teacher-facilitator role, to more effectively integrate content and pedagogy (Asghar et al., 2012).

Implementation. The effectiveness of professional development can be gauged by teacher changes in practice that, ideally, lead to increases in student learning (Desimone, 2009; Fishman, Marx, Best, & Tal, 2003; Johnson, Kahle, & Fargo, 2007). It is noteworthy, however, that factors other than teachers' content and pedagogical knowledge can have significant effects on implementation of the strategies that teachers introduce in professional development programs (Asghar et al., 2012). These factors include first-order barriers to teacher change, defined as those obstacles that stem from the environment of practice and over which teachers have little control (Ertmer, 1999).

The studies reviewed revealed that intensity of professional development (Ravitz et al., 2012; Zhang et al., 2011), degree of school-level support (Bradley-Levine et al., 2010; Fallik et al., 2008; Rogers et al., 2010), teacher experience (Toolin, 2004), and the manner in which structural barriers at the school level are addressed during professional development (Asghar et al., 2012; Lehman et al., 2006; Paik et al., 2011; Pederson et al., 2007) influence the degree of PBL implementation in the classroom. Understanding the degree to which professional development programs attend to these factors can provide insight into ways to enhance classroom implementation of PBL.

Intensity of professional development. As noted, of the 16 studies reviewed, 14 satisfied Desimone's (2009) minimum criteria for duration. In regard to the professional development programs in which participants met for a minimum of 20 hours with follow-up activities, two studies specifically found that duration or intensity of professional development experiences positively affected PBL implementation in the classroom (Ravitz et al., 2012; Zhang et al., 2011).

A quasi-experimental study of teacher self-efficacy in teaching 21st century skills after PBL professional development suggested that more intense professional development experiences resulted in an increase in teaching and assessing 21st century skills (Ravitz et al., 2012). These findings were based on surveys of teachers who participated in varying

amounts of professional development and on self-reports of classroom practices to gauge program outcomes. The researchers concluded that teachers who participated in extended professional development (a weeklong summer institute) taught and assessed the 21st century learning skills association with PBL significantly more than did the groups who had received limited (a few days) or no PBL professional development. Interestingly, Ravitz et al. also found that all 44 teachers in the extended professional development group reported providing PBL professional development to other teachers, as compared with only 33% of the limited professional development group. This finding suggests that the extended engagement affected teacher beliefs to the extent that the teachers became active change agents who advocated for PBL.

The theme of extended professional development as a positive indicator for PBL implementation is echoed in Zhang et al.'s (2011) longitudinal case study of one teacher who implemented PBL for science teaching in a kindergarten classroom. Data drawn from interviews and classroom observations collected over four years suggested that the teacher's understanding of PBL as well as classroom implementation increased with successive years of attending two-week summer workshops and participating in action research projects. The researchers noted that this teacher increasingly extended PBL practices throughout the curriculum, changed assessment practices to better reflect the goals of PBL, and attributed much of the success to the sustained nature and active learning components of the professional development experience as well as to the sustained support system offered to teachers to develop PBL units (Zhang et al., 2011).

School-level support. Three studies identified support from peers, school administrators, and community partners as key factors in PBL implementation after professional development (Bradley-Levine et al., 2010; Fallik et al., 2008; Rogers et al., 2010). These studies explicitly addressed post-professional development support and its relationship to PBL implementation in the classroom and provided evidence that collective participation in professional development is a component of effective programs.

Rogers et al. (2010) reported that teachers in a technology-oriented PBL program struggled to adjust to new instructional practices due to a lack of collaborative opportunities and a lack of commitment from administration to PBL. Bradley-Levine et al. (2010) came to a similar conclusion based on a five-teacher case study of summer institute attendees. Their findings led them to conclude that school-level support was crucial to PBL after the summer professional development experience,

and, in fact, teachers “noted the need to have ‘critical friends’ within their school as well as outside of the school to grow and support PBL implementation” (Bradley-Levine et al., 2010, p. 16).

Similar findings emerged from interviews conducted by Fallik et al. (2008) with seven expert PBL teachers and 58 novice teachers after they attended an intensive workshop focused on constructivist, learner-centered pedagogy that utilizes PBL. Their findings indicated that support from other teachers at the school level was critical to classroom implementation of PBL. Interestingly, the novice teachers reported an increased understanding of PBL skills and benefits for students but perceived fewer benefits for themselves due to implementation difficulties, including lack of school-level support. This suggests that less-experienced teachers may benefit from additional post-professional development supports and is in keeping with Toolin’s (2004) findings that first year teachers were less likely to implement PBL in the classroom.

Goodnough and Nolan (2008) found that, even when provided with collaborative opportunities during and after a professional development course, teachers faced significant implementation difficulties. The action-research program used collaborative inquiry (CI) over an eight-month period to engage six elementary teachers, a program specialist, and a researcher/teacher educator in an initiative to explore and implement PBL. A group data analysis process provided evidence that students had trouble with collaborative work and teachers had difficulty in giving up control over the classroom and making on-the-spot modifications to lessons (Goodnough & Nolan, 2008). At the same time, however, the teachers recognized that the collaborative nature of the program facilitated adoption of PBL practices in the classroom.

Teacher experience. Personal context in terms of teacher experience also can influence the outcomes of PBL professional development. Toolin’s (2004) study focused on six middle and six high school teachers in New York City who participated in a Community of Science Educators (COSE) program composed of summer workshops and school-year professional development sessions. Despite ongoing school-year support from the development staffer, who also acted as researcher, only those teachers with five years or more of teaching experience reported a sense of efficacy with introducing the practices in the classroom. Teacher characteristics that positively correlated to PBL implementation included having a graduate degree in education, having more years of teacher experience, and attending a larger number of PBL workshops. Notably, two of the three first-year teachers in the program failed to adopt PBL as a classroom practice (Toolin, 2004), which suggests that novice

teachers require additional supports within and beyond professional development experiences.

Structural barriers. Several studies focused on challenges posed by district and state-level policies (Asghar et al., 2012; Lehman et al., 2006; Paik et al., 2011; Pederson et al., 2007). As a whole, the studies indicated that professional development providers and policymakers should take into account the effect of curricular mandates, standardized testing, and school-day structure on teacher ability to implement PBL. This highlights a particular need for professional development program designers to attend to Desimone's (2009) coherence factor to align teacher learning experiences with local contexts for practice.

Pederson et al. (2007), in their case study of ten sixth-grade science teachers who attended a PBL workshop oriented toward use of an online PBL program, concluded that, while the workshop design emphasized constructivist learning theory, it paid little attention to teachers' need to modify content or assessments to align with state curricular and testing standards. Interviews with eight participants suggested that support for "local adaptations" (p. 247) of PBL is critical. Similarly, the results of Paik et al.'s (2011) study of 77 science teachers who participated in an NSF-funded weeklong summer workshop suggested that teachers are more likely to implement PBL when state standards are addressed in the course of professional development. Pre- and post-participation survey results indicated that the teachers valued activities with close alignment to state curricular standards more than they valued other content.

In their review of teachers who attended Project INSITE (Institute for Science and Technology), a three-week summer institute geared toward improving science teaching in grades 5–9, Lehman et al. (2006) reported that the teachers had difficulties with implementation. The evaluation included one year of classroom observations, interviews with a convenience sample of 23 teachers, and pre- and post-participation questionnaires of the 38 teachers who had participated in a summer workshop. While the teachers collaboratively planned projects that aligned to state and national science standards and had ongoing support via a teacher-in-residence and follow-up meetings, they reported that PBL implementation was hindered by its time-consuming nature, difficulties in accessing materials, classroom management difficulties, and interference with curriculum coverage. Nevertheless, teachers reported that the advantages of PBL outweighed the disadvantages (Lehman et al., 2006).

Asghar et al. (2012) similarly found that school structure, curriculum, and state assessment measures can interfere with PBL classroom implementation. They noted that the Maryland PBL professional development

program faces additional implementation challenges because the program is based on an interdisciplinary approach to PBL. The researchers noted that school schedules and state assessment practices are not amenable to interdisciplinary work and PBL in general. The findings suggested that school administrators must recognize implementation barriers and provide support structures for integration of disciplines in PBL.

Student outcomes. It is important to note that teacher reports of PBL implementation are insufficient evidence of PBL effectiveness in the classroom. Rather, to gauge the ultimate effectiveness of teacher learning, we must investigate whether students benefit from PBL pedagogies instituted after professional development. PBL, by definition, is a pedagogy that focuses on the application of knowledge, and its outcomes for students are, therefore, difficult to measure using standardized assessments (Asghar et al., 2012; Hmelo-Silver, 2006). Rather than focusing solely on content knowledge acquisition, PBL also develops critical thinking, problem solving, collaborative work, and communication skills as well as the ability to apply content knowledge to real-life scenarios (Savery, 2006). However, of the three studies that specifically measured student outcomes subsequent to PBL professional development programs, two gauged student performance by standardized test results (Boulden, 2008; Foutz et al., 2011) and one by student attitudes toward science in addition to test results (Kanter & Konstantopoulos, 2010). The reliance on standardized test results and attitude surveys to illustrate student learning reflects the difficulties associated with assessing skills associated with PBL, including critical thinking, problem solving, and collaborative work, as well as the need for professional development programs to attend to PBL assessment issues.

Boulden (2008) conducted a two-year evaluation of the Advancing Young Adult Learning (AYAL) in-service training program for teachers who worked with 16- to 24-year-old students who were preparing to take the GED exam. In this case, trainers taught PBL strategies in conjunction with youth cultural competency (YCC) and case management (CM) principles, with a focus on collaborative problem-solving skills. Boulden used student persistence in the GED program and successful completion of the GED as measures of program performance. After AYAL implementation, the average length of GED program enrollment increased from 3 weeks to 20.64 in the second year, and the GED pass rates rose from 10% to 40.5% from the first to third years of the program. Boulden did not discuss features specific to the PBL component of the training, however, and an understanding of the effects of the PBL components of the program were confounded by the multiple foci of the professional development.

Foutz et al. (2011) also used standardized test results to gauge the

impact of PBL professional development conducted by a collaborative program between a university and a public school district. In this case, the five-day workshop focused on using the engineering design process to prepare 33 middle and high school teachers to use agricultural engineering problems in math and science teaching. Foutz et al. measured student outcomes using results from the Criterion-Referenced Competency Tests (CRCT) for eighth-grade students in math and science. The researchers reported that math and science achievement for participating students increased relative to the state average, although the study did not report the statistical significance of the findings.

Similarly, Kanter and Konstantopoulos (2010), in their assessment of a graduate-level course that supported implementation of the "I, Bio" PBL curriculum, used minority students' science test achievement gains and pre- and post-surveys of student attitudes toward science and science careers as a measure of professional development effectiveness. The authors noted that students' achievement gain was 5.5 times greater than the statistically expected increase for students who were transitioning between grades on a nationally normed science test. Interestingly, increases in teacher content knowledge correlated negatively with student attitudes toward science, with effect sizes ranging from -.03 to -.26, although Kanter and Konstantopoulos identified positive correlations between student attitudes and frequency of inquiry-based teaching methods, including PBL.

Discussion of outcomes. The findings on teacher content and pedagogical knowledge point to the complexity of PBL pedagogy. Teachers must find a balance between teaching content and supporting students as independent learners. It is revealing that teachers in the studies reviewed experienced a dichotomous relationship between content knowledge and pedagogy. This finding highlights the need for teachers to have a deep understanding of the teacher role as facilitator in PBL, which suggests that professional development for PBL should be designed with a specific focus on synthesizing content with pedagogical techniques and should support teachers in designing problems and lesson plans. These findings align with Desimone's (2009) content criterion, which stipulates that professional development activities should link subject knowledge with pedagogical knowledge. The findings also are in keeping with the active learning criterion, which characterizes effective professional development activities as those that engage teachers in hands-on, participatory learning.

Many of the teachers in the studies reviewed faced challenges in classroom implementation of PBL, and the findings point to the importance

of attending to collective participation while addressing the structural barriers that impede PBL implementation. Because school-level support emerged as an important factor that supports PBL implementation, it is likely that teachers with active communities of practice may be able to more effectively negotiate the school structural factors that can impede PBL, which highlights the importance of collective participation in professional development activities. Novice teachers reported less-frequent PBL implementation after professional development activities, which suggests that PBL pedagogies represent a significant departure from teaching methods included in pre-service teacher education programs and that there is a need for more intensely focused support elements for these teachers in professional development activities. Despite the difficulties in PBL implementation, collective participation, combined with attention to school-level barriers during professional development, may allow teachers to make adaptations to PBL curriculum and assessments that will provide coherence with school structure and policy.

Where student outcomes after PBL professional development were measured, the results indicated positive achievement gains. The focus of assessments, however, was on specific subject content and failed to address skills such as critical thinking, problem solving, and communication. The programs reviewed rarely addressed difficulties associated with assessing “deeper learning” (NRC, 2012, p. 21), and it is notable that teachers in Pederson et al.’s (2007) study specifically cited the need to adapt assessments and PBL practice to local situations. This highlights the importance of Desimone’s (2009) coherence factor, particularly in the realm of supporting teachers in adapting instructional practices and assessment tools to the contexts in which they work.

Conclusions

PBL instructional practices are, indeed, a complex undertaking for K-12 teachers. Attending to critical design features of professional development programs can enhance teachers’ understanding of PBL pedagogy and assist teachers in incorporating PBL into classroom practice. The findings of this review suggest that particular attention to collective participation and the formation of communities of practice, along with a fine-grained understanding of the structural contexts that teachers face, are components of effective PBL professional development. Much remains to be learned, however, and further research is needed to identify strategies to assist teachers in becoming effective PBL facilitators and overcoming various implementation challenges.

The research based on K-12 professional development in PBL is, at

present, quite limited. Many existing studies lack an operational definition of PBL or, when PBL is one of several goals of the professional development program, fail to tease out the effects of the PBL component. The almost universally small sample sizes and qualitative nature of many of the studies create a body of research that lacks generalizability as a whole, and weak descriptions of methodology create a further barrier to assessing the body of evidence. More research is needed to determine specific professional development factors that will aid teachers in making the shift to becoming Hmelo-Silvers' (2009) "expert learner" (p. 245), particularly in terms of ways to support teachers within school settings and to assist them in adapting PBL strategies into existing school structures. Research on ways in which professional development programs can initiate communities of practice and other school-level supports also could yield insights on how to support PBL implementation.

Although Desimone's (2009) criteria for successful professional development are necessary for PBL teacher learning, the professional development designer also must seriously consider the specific demands of PBL and the factors that impede its implementation. Specifically, the coherence and collective participation elements deserve special consideration. Attention to state and district mandates and logistical school constraints in the design of professional development programs can enable teachers to plan locally specific adaptations while preparing them for difficulties that they may face in implementing PBL (Asghar et al., 2012; Lehman et al., 2006; Paik et al., 2011; Pederson et al., 2007). Program designers should attend to the idiosyncrasies of assessing PBL learning, mandated content standards, and ways to create opportunities for interdisciplinary learning in schools. Likewise, collective participation in PBL professional development can ensure that teachers have the support of and access to active learning communities that increase the likelihood of classroom implementation (Bradley-Levine et al., 2010; Fallik et al., 2008; Rogers et al., 2010). Including school administrators in PBL professional development activities may be a first step to providing the school-level support that teachers require and may help in identifying the ways in which school structure can be made more flexible to accommodate the particular requirements of PBL learning.

The studies reviewed also indicate that there is a lack of connection between the higher-order thinking goals of PBL and the assessment tools used to measure student learning. Indeed, researchers resorted to standardized test scores and measures of content knowledge to evaluate student learning. The use of these assessments in lieu of evaluations of skills such as critical thinking and problem solving suggest that assessments designed to measure the types of 21st century skills that

PBL supports are largely unavailable to practitioners. Where assessment tools were offered within the professional development program, teachers felt pressure to modify these assessments to align with state content standards (Asghar et al., 2012; Pederson et al., 2007). In short, teachers who implement PBL are faced with the challenge of assessing “deeper learning” (NRC, 2012, p. 21) while being held accountable to state-mandated standards and assessments.

Can PBL answer the call for pedagogical reform to foster a culture of problem solving, critical thinking, and collaboration in our nation’s K–12 schools? While, to date, this question has no clear answer, it is apparent that any consistent efforts to implement PBL in the classroom have important implications for educational policy. The recognition that our schools must foster innovation and application of knowledge through teaching 21st century skills is misaligned with the current standards movement. PBL is a powerful tool that schools can use to foster critical thinking and problem-solving skills, yet rigid school schedules and lack of cross-curricular rigor create a less-than-amenable environment for PBL in K–12 (Asghar et al., 2012). Professional development for teachers and administrators can help schools find ways to modify PBL to fit into existing structures; however, there are significant barriers to and little immediate rewards for schools to do so. To truly foster critical thinking, problem-solving, and communications skills through PBL, there must be substantial policy changes with regard to standardized testing and curricular content mandates coupled with professional development supports that address the unique pedagogical demands of this teaching and learning strategy.

Shaw’s vision of teachers as learners journeying with their students is a pleasing one. PBL pedagogies create the school environment in which this journey can occur while fostering the skills that students need for success in the 21st century world. However, this vision can become a reality only with a supportive environment that begins in the halls of Congress and extends to each school building, administrator, and teacher.

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