

Facilitating Technology-Enhanced Problem-based Learning (PBL) in the Middle School Classroom: An Examination of How and Why Teachers Adapt

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Despite the challenges inherent in adopting problem-based learning (PBL) in the middle school classroom, successful PBL teachers are able to find suitable solutions. In this exploratory study we examined the perceptions and practices of five successful middle school PBL teachers regarding the specific difficulties encountered with PBL and the strategies they used to address them. Results suggest that while successful PBL teachers faced multiple challenges when implementing PBL, they created and adapted effective strategies to

successfully mitigate the obstacles. *Planning* approaches included adapting previous units, using a backwards-planning process, and starting small. *Implementation* strategies included using a variety of grouping strategies and providing greater structure through mini-lessons, daily checks, and access to a list of relevant web resources. *Assessment* methods included using rubrics to outline project requirements and monitoring daily journals to assess progress. Teachers articulated that the use of these techniques enabled them to engage their students in interdisciplinary content and learning processes that met or exceeded required academic standards.

BACKGROUND

Problem-based learning (PBL) is a student-centered instructional approach that anchors the curriculum in ill-structured, authentic problems (Hmelo-Silver, 2004; Savery, 2006). According to Jonassen (2000), an ill-structured problem is one that has both multiple solutions and multiple paths to the solution(s). In general, the problems used in PBL units tend to be complex, challenging, and open-ended, engaging students in choice-driven inquiry (Barell, 2007). Assessment methods can take a variety of forms, but generally include evaluation of the solution according to criteria that measures the extent to which students present integrated understanding and demonstrate extensive knowledge (Hmelo-Silver, 2004).

PBL tends to shift traditional student and teacher roles. Whereas the teacher generally identifies the academic topic for study, students decide which specific learning issues to pursue. Following this, students then search for relevant information, gather data, and suggest solutions to the problem (Lambros, 2004) while the teacher acts as a facilitator or guide, assisting students with instructional supports, oral and written prompts, and relevant resources (Savin-Baden, 2003). According to PBL advocates (Hmelo-Silver, 2004; Savery, 2006), the overriding benefit of PBL is that it helps students simultaneously learn both discipline-based content and problem-solving skills.

While much of the research on problem-based learning (PBL) has occurred within professional education (Abrandt Dahlgren & Dahlgren, 2002; Albanese & Mitchell, 1993; Dochy, Segers, Van de Bossche, & Gijbels, 2003), recent efforts have extended findings to K-12 settings. For example, some of the early results from K-12 contexts suggest that PBL can positively impact motivation (Pedersen, 2003), problem-solving and collaboration skills (Achilles & Hoover, 1996; Ben-Chaim, Fey, Fitzgerald, Benedetto, & Miller, 1997), content retention (Saye & Brush, 1999; Schneider, Krajcik, Marx & Soloway, 2002), self-efficacy (Cerezo, 2004), and transfer of learning (Pedersen & Liu, 2002), particularly among middle and high school students.

However, despite the concerted efforts of many educators to promote problem-based learning among K-12 educators (Gallagher, 1997; Hmelo-Silver, 2004; Ward & Lee, 2002), few teachers are using these approaches in their classrooms, noting that the implementation of these methods is challenging (Brush & Saye, 2000; Ertmer & Simons, 2006; Frykholm, 2004). According to Blumenfeld, Soloway, Marx, Krajcik, Guzdial, and Palinscar (1991), "Considerable research in classrooms indicates that carrying out this type of instruction is difficult. Even if teachers are sympathetic to such an approach, many are more comfortable and familiar with lecture and recitation situations" (p. 383).

Given the general lack of experience most teachers have with open-ended teaching strategies (Land, 2000), novice PBL instructors tend to encounter difficulties during all aspects of the process: planning, implementing, and assessing. Furthermore, when technology plays an integral role in the implementation of the PBL unit, initial challenges may be exacerbated or new challenges encountered. In the following sections we describe these challenges as they occur during each phase of the PBL process.

PLANNING

Planning open-ended learning activities tends to take longer than preparing traditional lessons (Brush & Saye, 2000; Dahlgren, Castensson, & Dahlgren, 1998; Gallagher, 1997). This is likely due to the fact that PBL planning involves anticipating learning needs rather than directing learning activities. In order to successfully plan a technology-supported PBL lesson, teachers need to be able to anticipate the many possible ways in which the lesson may progress and be prepared with relevant resources, regardless of which paths students decide to pursue. For novice PBL teachers, this can be both time-consuming and intimidating (Dahlgren et al., 1998).

As teachers begin to plan a PBL lesson or unit, they may find that there are limited commercial materials available for classroom use. Traditional K-12 textbooks and curriculum guides typically do not contain adequate resources to support teachers who choose to use a PBL approach. This forces teachers to find or create all of the materials themselves. This process can be difficult for teachers who feel they do not have free time to spare, especially when materials are readily available to support traditional lessons that cover the same content (Ward & Lee, 2002).

Implementation

When implementing a PBL approach, teachers need to be able to adopt facilitative roles, to manage student work without overly directing it, and to support students' efforts to become self-directed learners (Ertmer & Simons, 2006).

Role of the teacher. One of the biggest challenges that novice PBL teachers face as they begin using student-centered methods is that of assuming a facilitative role (Brush & Saye, 2000; Dahlgren et al., 1998; Frykholm, 2004; Ward & Lee, 2002). In general, the teacher in a problem-based learning approach acts as a guide who helps students collaborate to generate solutions to problems (Kolodner et al., 2003). The emphasis shifts from a focus on grades, competition, and public comparison with others to that of inquiry and understanding (Gallagher, 1997). According to Hmelo-Silver and Barrows (2006), an effective PBL facilitator supports students who must learn to self-direct their efforts, construct understanding, and develop evidence-based arguments to support their proposed solutions.

Managing student learning. Not surprisingly, learning to adjust to this new role may result in tension related to management issues. As teachers relinquish control of the learning process, they also may feel as though they are surrendering their authority in the classroom (Ward & Lee, 2002). As noted by one teacher (cited in Boud & Feletti, 1991): “I can’t handle this. I want to be in total control and PBL doesn’t allow that” (p. 132).

Teachers who attempt to facilitate student-centered activities in their classrooms often describe challenges related to managing group work (Brush & Saye, 2000; Kolodner et al., 2003). PBL, by nature, requires students to be involved in higher-level cognitive activities; students tend to make more mistakes, solicit more help, and complete activities more slowly than they would in a traditional learning environment, thus increasing the potential for disorder in the classroom (Doyle, 1983). A number of different activities often occur simultaneously in a PBL classroom and the rules may be completely different for both the students and the teacher (Blumenfeld et al., 1991).

Supporting self-directed learning. As noted earlier, expert facilitators must know how to facilitate the development of students’ self-directed learning (Hmelo-Silver, 2004), typically defined as assisting learners as they take control of their own learning. In a PBL environment this includes processes such as defining the central issues of the problem, finding relevant resources, monitoring progress, and connecting inquiry activities to learning (Ertmer & Simons, 2006; Hmelo-Silver & Barrows, 2006). Supporting learner self-direction may be more difficult for K-12 teachers than those in higher education since younger students, including middle school students, may not have had previous experiences examining their thought processes or reflecting on their learning (Gallagher, 1997; Kolodner et al., 2003). Guiding and monitoring the individualized learning processes of 20 to 30 students can overwhelm teachers. To avoid these difficulties, teachers may be tempted to present the PBL problem to their students and then simply lecture about it (Simons & Klein, 2007). Unfortunately, this may diminish the effectiveness of PBL (Gallagher, 1997; Simons & Klein).

Assessment

Assessment of PBL outcomes also offers challenges that are not present in the traditional classroom (Blumenfeld, 1991). Since there are many possible solutions to PBL problems, as well as many possible paths to take to those solutions, assigning conventional letter grades may be difficult (Ward & Lee, 2002). A number of researchers (e.g., Blumenfeld et al., 1991; Brush & Saye, 2000; Ward & Lee, 2002) agree that formulating assessment criteria that are compatible with the goals of PBL can be difficult. Since student-centered instruction focuses on developing problem-solving, research, and collaboration skills, assessment measures need to move away from an emphasis on isolated facts to the meaningful application of authentic knowledge (Gordon, Rogers, & Comfort, 2001). While teachers will want to use measures that realistically reflect what students have accomplished while working in cooperative groups, they also need to assign individual grades for accountability purposes and to determine if students have mastered content-area standards (Ertmer & Simons, 2006). According to Blumenfeld et al. (1991), “assessment is more difficult with project-based learning, because techniques to diagnose student understanding of project-based learning are less structured, more clinical, and more time consuming than assessment of traditional learning” (p. 383).

State standards and standardized tests. In an era dominated by government legislation requiring accountability of students and teachers (U. S. Department of Education, 2001), most K-12 teachers in the United States feel pressure to cover academic standards and to prepare their students for standardized tests. Educators who are dealing with these pressures find it difficult to justify the use of class time for problem solving activities (Meier, Hovde, & Meier, 1996). Teachers may worry that because they have less control over what content is covered in a PBL classroom, gaps will occur in students’ learning if too much time is spent on inquiry-based instruction (Hung, Bailey, & Jonassen, 2003; Gallagher, 1997; Hmelo & Ferrari, 1997). Since PBL tends to encourage students to investigate specific issues involved with a problem, they may not interact with other content that is also part of the curriculum (Hung et al., 2003). And while most standardized tests use multiple-choice questions to measure student performance, PBL assessments tend to be product-driven and knowledge-based (Ward & Lee, 2002).

Time Constraints

In addition to the challenges listed above, teachers also worry about time constraints experienced during the school day. Most middle schools and high schools in the U.S. are divided into subject-based class periods that are usually less than an hour long. These rigid schedules can make it difficult to implement a PBL unit successfully (Ward & Lee, 2002). A number of studies have shown that teachers who use PBL in their classrooms find the time

constraints difficult to handle (Blumenfeld et al., 1991; Brush & Saye, 2000; Dahlgren et al., 1998). In previous efforts, middle and high school teachers became frustrated when they were unable to complete a PBL lesson in one class period (Blumenfeld et al., 1991). Additionally, problem-solving activities were proclaimed unsuitable simply because of the time involved in implementing them.

The Role of Technology

While technology can be used to overcome a number of the challenges outlined above, it may also introduce new sets of challenges. For example, Internet access dramatically changes how students conduct research and access resources (Kozma, 2003; National Center for Education Statistics, 2000). As such, teachers who integrate technology into classroom activities find themselves dedicating a significant amount of energy trying to overcome a variety of barriers including time, resources, and support (e.g., Ertmer, Gopalakrishnan, & Ross, 2001). Furthermore, while computers may play an important role in helping learners organize notes and information and provide a way for teachers to isolate and deliver content to all learners on a just-in-time basis (Neiderhauser & Lindstrom, 2006), teachers will need to address the issues associated with judging the merits of online sources and interpreting findings (Simons & Klein, 2007). This suggests the importance of understanding more about the role of technology in supporting teachers and learners in PBL.

PURPOSE

While it is important to understand the challenges teachers experience when adopting PBL methods, it is perhaps even more important to understand how and why effective PBL teachers make this approach work in their middle school classrooms. This study was designed to examine the perceptions of experienced PBL teachers regarding the challenges they encountered when using technology-supported PBL. By examining the practices of successful PBL teachers, we hoped to discover the practical strategies they used to address the inherent challenges of this approach. Thus, the results of this study may lead to more support systems and scaffolds for novice PBL teachers, more appropriate assessment instruments, and a wider variety of materials that would enable more K-12 teachers to use PBL effectively in the classroom. Specifically, our research questions included:

1. How do teachers characterize the challenges of technology-enhanced PBL? What strategies have they used to address these challenges?
2. Why do teachers persist despite the challenges associated with PBL? What rewards are associated with PBL?

METHOD

Research Design

An exploratory, qualitative case study research design was used to examine teachers' perceptions of tensions and challenges experienced while implementing PBL. As Merriam (1998) indicated, case study design is used in order to understand context-related phenomenon anchored in real-life situations. The case study was an appropriate method of inquiry for this study since we aimed to gain an in-depth understanding of a particular phenomenon in its natural setting. In particular, we sought to gain greater insight regarding how teachers address the challenges of technology-enhanced PBL and why they persist despite any difficulties. Data were collected via face-to-face interviews, a focus group interview, and a series of informal classroom observations.

Participants and Setting

Five middle school teachers were purposefully recruited to participate in the study during the 2005-2006 school year based on identified criteria: (1) currently working as classroom teachers and (2) having used technology-enhanced PBL for at least four years. All participants taught at the same middle school located in a small rural community in the Midwest and all were female. Beginning in Fall 2000, every teacher and student at the middle school had been given individual, personal access to a laptop computer as part of a U. S. DOE Technology Innovation Challenge Grant. This technology initiative was designed to combine the power of one-to-one computing with problem-based pedagogy in order to improve teaching and learning at the middle school level. As part of this effort, the teachers also were given access to a wide variety of professional development programs (workshops, summer institutes, credit-based courses) focused on improving both their technology skills and their knowledge and practice of PBL. The five participants in this study represented a variety of content areas: mathematics, English as a Second Language (ESL), language arts, and science. Each teacher previously had participated in formal professional development programs offered throughout the five-year funding period, though it should be noted that the language arts teachers participated in almost every opportunity, while the ESL teacher began attending during year four. Table 1 provides more specific information about each teacher's background (all names are pseudonyms).

Data Collection

Face-to-face interviews, a focus group interview session, and classroom observations provided the research team with in-depth data about challenges experienced while planning and implementing a PBL approach. A semi-structured interview guide was developed based on the research questions

Table 1
Demographic Information for PBL Teachers

Name	Grade	Subject	Years Teaching	Years in District	Education Level	Formal PBL Experience	Informal PBL Experience
Annie	6-8	ESL	10	10	BA-Elem Ed	2 years	6+ years
Connie	6	Math	8	6	MS + 6 cr	4 years	5 years
Sheila	7	Sci	18	16	MS + 8 cr	3 years	18 years
Tonya	6	LA	9	7	BS + 32	6 years	6 years
Martha	6	LA	18	18	BS + 40 cr	6 years	17 years

and review of related literature. The final form of the interview guide included three main sections related to using PBL. Sample questions were provided as follows:

- *Planning a PBL unit.* In planning a PBL unit, where did you start? How did you come up with the driving question? What difficulties did you have during the planning process?
- *Implementing the PBL process, including transitioning to a facilitative role.* How did you organize the activities for the students? How did you ensure that students were working toward the driving question and learning content? How comfortable did you feel acting as a facilitator during PBL?
- *Assessing student learning and meeting academic standards.* How have you approached assessment in PBL? How well do you think you meet your learning objectives when teaching a unit using a problem-based learning approach? What's the most challenging part(s) of assessing students?

Face-to-face interviews were conducted individually with each teacher in spring 2006. Each interview lasted approximately 30-45 minutes, was audiotaped, and transcribed. The following fall, a focus-session protocol was developed out of the themes that emerged from the interviews. Questions were developed to probe more deeply into the challenges teachers faced using PBL (i.e., "How does adding technology complicate PBL planning and implementation?") as well as their approaches to addressing those challenges (i.e., "What are some specific strategies for addressing these issues?"). The focus group was conducted with four of the five teachers at the end of a school day (the fifth teacher was on maternity leave) and lasted for 60 minutes. The session was audio recorded and transcribed.

Classroom observations were performed throughout the school year while each teacher was facilitating a PBL unit. Observations were informal and conducted for the purposes of capturing the strategies the teachers used

to support student inquiry while managing the PBL process. Each teacher was observed four to six times, depending on researcher availability.

Data Analysis

Analysis began by transcribing all interviews, including the focus group, and summarizing observation notes. Interview and focus group transcriptions were read and reread to determine themes related to specific challenges in planning, implementing, and assessing PBL units in the classroom. As different categories of challenges were identified, such as changing roles, managing group work, and assessing student learning, we looked, more specifically, for strategies that the teachers used to address those particular challenges. These were then triangulated with observational data that either confirmed or disconfirmed teachers' uses of these strategies. Lincoln and Guba (1985) recommended that qualitative results be evaluated using the standard of trustworthiness, as established by credibility and confirmability. In this study, *credibility* was gained through triangulation of multiple data sources. The use of multiple researchers led to *confirmability* of the data. That is, the two lead researchers examined the data individually and then collaboratively as a means of developing consensus regarding the meaning of, and implications for, the relevant coding categories and emergent themes.

RESULTS AND DISCUSSION

As noted earlier, this study was designed to examine how teachers characterized and addressed the challenges of technology-enhanced PBL as well as to discern why teachers persisted despite the challenges.

Teachers' Strategies for Addressing the Challenges of Technology-enhanced PBL

lanning. All five teachers agreed that, initially, planning a PBL unit takes more time than planning other units. For example, Martha stated, "I think that you are just initially overwhelmed. You look at that and see all the preparation you have to do to initiate a PBL, and you go, 'I don't want to do that; that is too much work.'" Planning issues described by the teachers included choosing a good question, being able to anticipate students' questions and learning needs, and gathering the appropriate resources, including web-based resources. As noted by Sheila in her interview:

What was I going to plan for? That probably is the most challenging, is figuring out: Are they going to go in this direction, or this direction, or this direction? And do I have materials to cover all of the above?

Teachers used a number of strategies to address these challenges. For

example, Tonya described a backwards-planning process that allowed her to anticipate students' questions, responses, and potential problems. Annie described how she first went through the whole problem herself to identify potential glitches. All five teachers spent time up-front finding relevant web resources so that students would not get sidetracked trying to find relevant and appropriate sites. For example, Tonya described how she and the other language arts teacher supported the students' Internet search efforts:

We give the students a lot of background support. We just don't throw them out there and say, "Just go and do it." We actually track the websites for them. We have those all set aside so we know where they are going and we know that they [the websites] are going to be helpful for them, [and] that they work. We try to give them a lot of, not answers, but pointed ideas about where you can go.

Suggestions were also made to use a unit that has been used in the past (Tonya) and to "keep it small" (Martha) so as not to overwhelm either the teacher or the students. This is similar to suggestions made by Barell (1998) and Ertmer and Simons (2006): teachers are advised to begin with a small inquiry unit lasting only two or three class periods, or perhaps to implement a PBL unit after having already introduced some of complex concepts via a teacher-directed unit. As one example, the two language arts teachers in this study engaged their students in a 2-3 day practice unit on "What makes a good friend?" as a way to prepare students for the types of experiences they would have during their first PBL unit on "Why should I care about rainforest deforestation?"

Implementation. Implementation challenges were related, primarily, to managing small group work as well as integrating the effective use of technology tools and resources into students' problem-solving activities. The teachers all described the importance of being able to let go and allow students to take responsibility for their own learning. Yet, despite this willingness to give students control of their learning, teachers still experienced challenges during implementation, especially during small group activities. Knowing how to group students (e.g., by ability, interest, learning style, random assignment, student choice, or a combination) seemed to pose the biggest concern. Furthermore, observations revealed that teachers did not have many strategies at their disposal for addressing the few non-engaged groups beyond directing students to get to work. For example, during one session in Martha's classroom, a group of students could not agree on a major direction of the project, which required students to suggest an improvement to the community. When taking their disagreement to the teacher, she consistently and firmly maintained the same directive: you will need to work out the problem. In discussing this later with the teacher, she

acknowledged this as a common problem of middle school students in general, but stated that in the next PBL unit she would likely find a way to group students by a more common interest.

Particularly frustrating for the science teacher, Sheila, was the task of integrating less-capable students into the demands of a PBL approach. While some students are able to benefit from working with more capable peers during a PBL unit, others get left behind due to poor reading ability and/or poor study habits and self-directed learning skills (Simons & Klein, 2007).

The remedial class by far has been...the most challenging. A lot of those kids in that remedial class can't read and yet I am supposed to teach them DNA and chemistry? They need to be learning to read. That by far has been the biggest frustration because I have got two points of view: Do you leave them out and make them feel even worse than they already do? Or, do you give it a shot and hope for the best? My thought has always been give it a shot. Give them what they need. Help them read through the material and hope. That is a really, really rough one.

In the focus group, Sheila elaborated on this theme further: “[Some of] these kids have probably been retained at least once if not twice.” She went on to state that she added greater structure and more assistance for those struggling students. However, our observations showed little, if any, evidence of this teacher altering her methods to support the remedial class of students in a different manner than that which was implemented with her regular classes.

One strategy used by Martha was to offer a substitute project for those who were not experiencing success within their small groups:

We sometimes have alternate activities that are probably not quite as hard, but still on the same topic. For the community PBL...I've used “design-your-own-park.” It's along the same lines but it's something a bit different. And they don't have to do research because usually that's the struggle with some of those kids.

Observations confirmed that within almost every class period, one or two of the students worked on independent projects. This was integrated into the normal classroom experience, and these students received neither special attention nor isolation for participating in the alternative assignment.

In addition to providing support for the struggling groups, the teachers described a variety of strategies to support all students: presenting mini-lessons, creating websites with links to relevant resources, using rubrics that clarified expectations for project components, and implementing daily checks to keep students on task. These strategies were coupled with the teachers' ability to be flexible and adopt what Connie called the “mindset of a facilitator.”

Additional implementation challenges related to using technology either as an information resource or as a development tool. Using the example of a unit about Minamata disease (i.e., a massive pollution problem that hit Japan after the Second World War), Sheila described her concerns about helping students find relevant information:

How was I going to find the information that these kids desperately needed that wasn't out there or it wasn't translated? That was my biggest fear. My biggest concern was where was I going to find it? I can't go to Japan to get it. What am I going to do?

Still, Sheila noted that finding information was so much easier now than when she first implemented the unit using CD-ROM databases, which were both expensive and difficult to use: "With the advent of the Internet, there were no worries about supplies anymore. I type in Minamata and I get a million hits. A lot of it is being translated from Japanese to English, especially if you have the translator on the computer, which we do." Overall, technology resources, particularly the Internet, seemed to ease some of Sheila's concerns about having to find relevant resources at the point of students' need. During our classroom observations, we also noted that she developed topical notebooks that students could reference during their investigations. Each notebook contained relevant information, most of it printed from the website resources. Sheila mentioned the notebooks alleviated problems associated with students forgetting their computers or unreliable access.

Another teacher, Annie, spoke specifically about the challenges associated with using technology as a development tool. She described how frustrating it was "to lose valuable time" when the technology "went down" as well as how important it was to know the required skills before introducing them to your students:

Make sure you know your technology. With movie making...I had never edited a film and I had planned a couple of days to edit and about literally threw my computer out the window by the end. I needed more time to review MovieMaker. Know your stuff before you get into it because that just wastes time as far as I'm concerned.

In general, these frustrations were due, primarily, to not being sufficiently prepared to use the available technology in an efficient manner. Given that all five teachers indicated that time was the biggest constraint in using PBL, teachers were particularly frustrated when, as Annie said, time got wasted "trying to make the technology work."

Assessment. All of the teachers recognized that assessment of student learning was tricky. As Annie noted:

That is always a sticky thing with PBL, you know. How do you evaluate? So we are going to be doing...some self-reflection, self-evaluation, some group evaluation, and teacher evaluation throughout this process? And then we will probably have some kind of a rubric at the end.

All five participants used these same formal and informal assessment strategies in various combinations. For example, Sheila regularly read and commented on students' journals, which were used to track their learning and record ongoing reflections. Another teacher, Martha, frequently reminded students what she would be looking for in their final projects, and referred them to exemplary models. Like Annie, the other teachers in this study tried a variety of techniques, sometimes changing their strategies with each unit. As Martha noted, "Every year I try something different. I haven't found anything I'm 100% happy with. A lot of times it ends up being a combination." We observed that in her classroom, student assessments usually took the form of multi-dimensional projects, such as a persuasive narrative accompanied by a group presentation.

It should be noted that although these teachers expressed having initial concerns about meeting required state standards, they all quickly realized that a PBL approach allowed them to meet many more than expected. As noted by Sheila: "I was worried about covering standards, but I realized very quickly that you actually cover double of what you first planned."

Other Challenges. Teachers noted that the biggest frustration related to time. Annie said, "Time. I always underestimate the time that it's going to actually take...for me, that's the biggest thing." This was echoed by all five teachers, and is consistently noted in the literature (Brush & Saye, 2000; Hoffman & Ritchie, 1997; Rhodes, 1999). PBL requires more planning time as well as more, and longer, blocks of time for implementation. These were factors that, for the most part, were out of teachers' control. But because teachers were convinced of the benefits of this approach they did not allow this to deter them. When asked about the challenges, Annie stated, "The overall [benefits] far exceed the problems."

Reasons for Persisting with PBL

Overwhelmingly, the teachers in this study highlighted the benefits and minimized the frustrations related to using PBL because they believed, first and foremost, this was an approach that, according to Tonya, was "good for kids." In elaborating on this theme, the teachers most prominently discussed PBL as a means to meet academic standards, foster interdisciplinary approaches, and engage students.

Meeting academic standards. All the teachers in this group addressed the ability to meet academic standards through PBL in ways that worked for most students. Martha summed this up in the focus group by saying:

I mean if you go from beginning to end, everything they learn in researching...[They] learn to cite the resources or bibliography... And there's [sic] all kinds of new technological standards they are meeting... Then you go into the actually creating the PowerPoint. Well, that's writing. They do note cards, note taking. They revise. They present, not once but twice. I mean if you go through all that I bet you I can hit half the standards. Easy.

Similarly, Annie remarked, "[For] ESL, [PBL] encompasses so much of the language, you know, we're reading, writing, speaking, listening, everything in one fell swoop." The teachers clearly found PBL allowed them to consistently meet academic standards.

While there is little research that has examined how secondary students who engage in PBL units demonstrate progress toward meeting academic standards on standardized tests, these results represent an important first step toward understanding how this can be accomplished. At least according to these teachers, one strong reason for persisting with PBL is the additional value that this approach brings; the teachers described being able to cover academic standards and to provide students with meaningful problem-solving experiences in the process. While these results are anecdotal, Saye and Brush (1999) reported similar findings in their comparison of two secondary social studies classrooms, one of which was taught traditionally while one was taught using PBL by the same teacher over the same period of time. While there were no significant differences on the measure of content knowledge, students from the PBL group significantly outperformed the comparison group on an essay scored for higher-order reasoning. This demonstrates the value added in PBL environments, though more research is needed to understand the conditions under which this is most effectively and efficiently accomplished.

Fostering interdisciplinary approaches. The teachers also discussed how PBL fostered interdisciplinary instruction. Sheila summed this up in a discussion comparing her interdisciplinary approach with the segmented approach to education she experienced as a student:

They have to learn to solve a problem. And if they don't, we have not – we have failed them...[We] have not given them what they need to survive the real world. Which is what we found in the 70s and 80s. You come out of that trivia age, where it's in a book, you can look it up, memorize it...It's not that way anymore. The world has changed.

Sheila's statements are consistent with our observations of her instruction. For example, in one class period, we watched her teach students how to deliver a persuasive presentation, covering techniques that ranged from organization of the content to delivery of the presentation.

The math teacher, Connie, expressed similar convictions regarding her use of PBL: You know, people say, “Oh all you do is PBL. You are wasting your time because you aren’t meeting the standards.” I don’t think they really contemplate all the standards, all seven areas of standards, that you are really utilizing and you are pulling in from the other subject areas at times.

Connie elaborated on the interdisciplinary nature of a new PBL unit currently being planned in collaboration with one of the language arts teachers. In this discussion, both described coordinating efforts and making sure a variety of content could be represented in the unit. Because they previously had done this for a number of years, the interdisciplinary planning process was seamless, with both teachers being able to elaborate on the others’ content standards.

It is no surprise that these teachers highlighted the interdisciplinary nature of problem-based learning, especially considering that PBL was initially formalized to address difficulties with segmented, inert knowledge (Barrows & Tamblyn, 1980). In fact, this may account for the popularity of PBL in a variety of disciplines from health education (Geller et al., 2002) to engineering (Wood & Mack, 2001). In the middle school setting, Simons, Klein, and Brush (2004) found success with an interdisciplinary PBL program emphasizing science, social studies, and language arts content, which was cited by the teacher as a primary strength of the unit. As noted by Barell (1998):

Meaningful learning results from the connections and relationships discovered and created among myriad pieces of information one receives...Learning can become more meaningful and, thereby, long-lasting if students are successful at transferring knowledge, skills, and attitudes among different subjects. (p. 139)

Engaging for students. One final reason that these teachers persist is that they find students generally to be more engaged when using a PBL approach. Annie discussed this as one of the most positive aspects of PBL:

They’re the ones deciding who’s doing what. They want to start yesterday. First couple of years, they were meeting after school by themselves because they couldn’t stand it because I wasn’t going fast enough...They didn’t have enough time in class, you know.

Connie echoed a similar theme: “The kids love PBL because they are posed with a problem and there is no right answer. They get to be creative in math class.” She went on to elaborate, “I know the kids like PBL better, definitely, because it is more relevant to them than a bunch of numbers on a piece of article.” Martha put it this way: “[There] is never going to be a concern about kids being bored.”

These findings regarding positive attitudes are supported by the PBL research in both post-secondary (Albanese & Mitchell, 1993) and secondary contexts. Simons et al. (2004) and Simons and Klein (2007) found that middle school students had extremely positive attitudes toward their first PBL experience, despite a number of frustrations regarding time and problems finding information they needed. Similarly, in the field-test report with over 1,000 students of Alien Rescue, a PBL science unit for the middle school grades, Liu, Williams, and Pedersen (2002) reported overwhelmingly positive comments from both students and teachers. This line of research suggests that students – secondary and post-secondary alike – respond positively to PBL, which also may help to explain why teachers persist in using this method.

Limitations and Suggestions for Future Work

Besides having a small number of participants, the results of this study are limited by our relatively homogeneous sample. All five teachers were strong advocates of the PBL method and thus were not able to provide the perspective of those teachers who tried PBL but did not persist. Furthermore, the timing of our study may have limited the participants' ability to recall their initial frustrations with the method. For a more complete understanding of how and why teachers adopt PBL, future work should include teachers who are at the early stages of adoption, as well as those who decide, for whatever reasons, not to continue using the method.

IMPLICATIONS AND CONCLUSIONS

While the teachers in this study recognized the challenges to using PBL, none of them felt overwhelmed by them. Rather, they implemented effective strategies that successfully mitigated these difficulties. Table 2 presents a summary of the recommended strategies stemming from the findings with these teachers.

The teachers in this study described strategies to address specific PBL challenges related to planning (e.g., starting with a familiar unit, keeping the unit small, anticipating students' interests and questions, and locating relevant resources), implementing (e.g., presenting mini-lessons, creating supports for struggling students, using rubrics to clarify project expectations), and assessing student work (e.g., combining formal and informal assessment techniques, providing opportunities for reflection and peer review). Additionally, teachers described strategies for incorporating technology resources and development tools into their PBL units (e.g., finding relevant resources ahead of time, practicing required skills). By sharing these strategies with novice PBL teachers, it is expected that we can support their early efforts at using these types of open-ended instructional approaches. This, in turn, should lead to fewer frustrations and thus, greater levels of persistence.

Table 2
Recommended Strategies for Planning, Implementing, and Assessing PBL Units

	Challenges	Recommended Strategies
Planning	<ul style="list-style-type: none"> ✓ Developing a good question ✓ Anticipating students' questions and learning needs ✓ Dealing with complexity embedded in real-world problems ✓ Gathering appropriate resources 	<ul style="list-style-type: none"> ✓ Adapt previous units; Use questions embedded in local events and issues ✓ Use backward-planning process; Revise units for the subsequent year ✓ Start small; Introduce complex concepts via teacher-directed lessons; Provide feedback ✓ Create web-lists of relevant resources
Implementation	<ul style="list-style-type: none"> ✓ Managing small group work ✓ Allowing students to take responsibility for their own learning ✓ Integrating less capable students into the PBL method ✓ Integrating effective use of technology tools and resources 	<ul style="list-style-type: none"> ✓ Use multiple grouping strategies depending on the task ✓ Provide supports that address students' needs: mini-lessons, web-lists of relevant links, rubrics to clarify expectations; Allow students to struggle ✓ Use homogeneous groups; Provide alternative projects; Provide additional assistance (worksheets, templates, etc.) ✓ Make sure you know your technology; Have a plan B; Find relevant web resources ahead of time
Assessment	<ul style="list-style-type: none"> ✓ Measuring individual learning during group work and from group products ✓ Measuring learning outcomes from open-ended activities 	<ul style="list-style-type: none"> ✓ Use a variety of methods (self-evaluation, peer evaluation, teacher evaluation) ✓ Use ongoing methods to assess progress and identify problems early on; Provide feedback on early drafts and require revisions

However it is important to note that these strategies were reinforced by teachers' flexibility and their strong beliefs in a student-centered approach. Given teachers' levels of internal motivation, how can we convince other teachers, who are not similarly motivated, to try PBL? Especially for those who do not have a flexible mindset, as recommended by Connie, how can we offer the support needed to take the plunge? These teachers suggested the need for time, which administrators may be able to accommodate, as well as the benefits of having peer mentors available who had used the PBL approach. Not only can mentors provide models of effective use, but they can also address novice teachers' concerns about meeting standards, monitoring students' work, and making mistakes.

As researchers have noted, PBL has yet to make strong inroads into K-12 classrooms (Brush & Saye, 2000; Frykholm, 2004; Hmelo-Silver, 2004). However, understanding more about what works for teachers and why they persist gives us more insight into the successes and motivations of teachers. Thus, we are better equipped to help novice PBL teachers mediate some of the tensions and challenges experienced, especially in the early stages of adoption.

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