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Beyond Beliefs: Teachers Adapting Problem-based Learning to Preexisting Systems of Practice

John L. Pecore

Abstract

Problem-based learning (PBL) is a constructivist method of instruction aligned with the science educational reform movement to increase scientific literacy for all Americans. As such, PBL instruction is an increasingly popular topic for professional development workshops offered to teachers in secondary learning environments. This research presents a case study of four teachers' alignment of classroom practice with constructivist principles after participating in a one-week PBL workshop. Teachers assimilated PBL instruction into their current system of teaching; therefore, despite congruent beliefs, those teachers without a constructivist system of practice taught the PBL method with less alignment to constructivist principles. This discrepancy between beliefs and practice could be addressed by helping PBL workshop participants contemplate how components of PBL encourage reform-based constructivist practices and by assisting teachers with modifying preexisting routines to better assimilate PBL instruction.

Keywords: problem-based learning, constructivism, teacher professional development, science education

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Introduction

Problem-based learning (PBL) is a type of inquiry pedagogy, originating as an instructional method from Canadian medical schools in the early 1970s (Rhem, 1998; Weller & Karp-Boss, 2007), where students collaborate to investigate science content and social implications involved in a real-world problem. A PBL approach to teaching is gaining popularity in school curricula throughout the United States as a way of increasing student gains in cognition, development of skills, independent learning, cooperation, and motivation (Chiappetta & Koballa, 2005; Smith, Powell, & Wood, 1995; Sonmez & Lee, 2003; Weller & Karp-Boss, 2007). PBL is a method of instruction that develops learners' knowledge and problem-solving skills through real-world problems (Albanese & Mitchell, 1993; Weizman, Covitt, Koehler, et al., 2008). During PBL instruction, students are led through a process that involves objectives, problems, research experiences, solution development activities, and assessments (Torp & Sage, 1998). Students working in groups are presented with a problem and asked to analyze preliminary data. With instructor assistance, the group determines the issues to research. Groups then share their research with the class, receive additional information and/or conduct an exploratory activity, and continue researching the problem. For PBL assessment purposes, groups pull together their knowledge and prepare a final solution to the problem.

This curriculum approach aligns with the National Science Education Standards to increase scientific literacy, which endorses a curriculum that focuses on meaningful student learning, depth over breadth of understanding, and learning in context (American Association for the Advancement of Science [AAAS], 1991; AAAS, 1993; National Research Council [NRC], 1995). Additionally, PBL supports the Next Generation Science Standards K-12 education framework to engage students in science and engineering practice, cross-cutting concepts, and disciplinary core ideas (NRC, 2011). The National Science Teachers Association (NSTA), literature published by NSTA Press (e.g. NRC, 1995), and the National Science Foundation (NSF) funded professional development provide resources to assist educators with implementing reform-based practices.

Each year since the mid-1990s, groups of teachers participate in PBL workshops, initially offered by medical universities, but more recently by numerous organizations including community colleges, often in partnership with four-year institutions. Generally, the goal of these workshops is to prepare teachers to facilitate PBL lessons that connect better with students in an effort to improve scientific literacy and interest in science. Reform-based inquiry teaching methods can run counter to the classroom culture teachers develop over years of teaching. For this reason, PBL poses several challenges for both teachers and students likely to be uncomfortable with different roles and responsibilities required for an open-ended classroom culture (Ertmer & Simons, 2006; Land, 2000). Thus, it is imperative that PBL workshops provide effective professional development that addresses necessary classroom culture components of reform-based science instruction.

Previous literature reveals little about how professional development translates into teacher practice (Fishman, Mark, Best, & Tal, 2003; Walker, Recker, Robertshaw, et al., 2011; Wayne, Yoon, Zhu, et al., 2008). Luft (2001) concluded that change in practice to reform-based instruction may be attributed to teachers' student-centered beliefs. However, changing beliefs is difficult (Pajares, 1992) and is unlikely to occur due to a professional development workshop. Similarly, Supovitz and Turner (2000) posit that teacher attitudes towards reform influence teaching practices. They found that teachers more sympathetic towards reform more frequently use inquiry-based practices and maintain a more investigatory classroom culture. In a review of the research on teachers' professional development practices, Opfer and Pedder (2011) state that perceptions and beliefs of teachers are significant predictors of change, but unfortunately are not easily altered. Research suggests teachers' beliefs and practices may change if provided with more and better opportunities for field and classroom experiences, reflection, challenging oneself in a safe environment, and applying knowledge about teaching and learning. However, few studies empirically connect professional development activities to specific changes in teacher belief or subsequent teaching practice (Opfer & Pedder, 2011).

After reviewing the research literature, Mansour (2009) concluded that the relationship between beliefs and practice revealed little agreement and that teacher beliefs and practices might be formed and reformed. Haney, Czerniak, and Lumpe (1996) determined that beliefs significantly influence practices, which is corroborated by Pajares (1992) who cites several sources supporting a similar assumption that beliefs best indicate personal decisions. However, some researchers like Luft (1999) and Carroll (1999) argue that reflecting on practice can change beliefs (Mansour, 2009). The general consensus is that teacher beliefs and their practices are complex. Some studies suggest that beliefs are congruent with practices, other studies show that beliefs can be contradictory with practices, and still other studies indicate that beliefs have an indirect effect on practices (Mansour, 2009; Savasci & Berlin, 2012). Opfer and Pedder (2011) suggest that the complex interplay between knowledge, experience, and practice with beliefs influences the rejection or adoption of new learning.

According to Savery and Duffy (1995), PBL provides one of the best examples of a constructivist learning environment by adhering to the theoretical principles of constructivism. Thus, teachers with a constructivist learning belief system would more likely practice PBL instruction that is congruent with constructivism (Supovitz & Turner, 2000). Constructivism aligns well with PBL as it places emphasis on the learner's ownership of ideas and a personal interpretation of knowledge. In theory, students become less dependent on teachers and texts for answers, and more reliant on the content knowledge they acquire through personal research, their own judgment, and common sense.

Together, Savery and Duffy's (1995) instructional principles and Taylor, Fraser, and Fisher's (1997) five values of constructivist learning environments provide a framework

helpful for interpreting instructional methods such as PBL. These five constructivist learning environment principles are as follows:

1. Personal relevance relates content to students' everyday interests and uses their everyday experiences as a meaningful context for learning.
2. Critical voice involves fostering students' critical attitudes toward the teaching and learning activities by encouraging a sense of personal autonomy as a way of providing student ownership.
3. Uncertainty deals with learning that is reflective of the discipline's complexities, such as understanding scientific knowledge as evolving and provisional, shaped by social and cultural influences, and arising from human interest and values.
4. Shared control includes active engagement through inquiry where the learning environment values and challenges learners' thinking by providing students with opportunities to manage their own learning activities and negotiate social norms of the classroom.
5. Student negotiation engages students in collaboration to support testing ideas against alternative views, reflecting on the viability of their own ideas, and encouraging development of self-regulated learners.

The purpose of this study was to explore teachers' learning environments and classroom practices during PBL instruction. Teachers of PBL curricula devise learning environments that are consistent with their pedagogical understanding of constructivist learning theory (Savery & Duffy, 1995). By identifying the teachers' operational understanding of constructivism, a foundation was built to interpret how teachers' implementations of PBL aligned with constructivist principles. The research question that guided this study is as follows: How do teachers' PBL instructional practices align with beliefs in constructivist principles?

Context of the Study

Description of Professional Development Workshop

The one-week summer PBL professional development workshop connected to this study aims to provide teachers with the understandings and skills for implementing PBL methodology and aligns well with nine essential characteristics of research-based professional development, which should be:

- be schoolwide;
- be long-term with follow-up;
- encourage collegiality;
- foster agreement among participants on goals and vision;
- have a supportive administration;

- have access to adequate funds for materials, outside speakers, substitute teachers, and so on;
- develop buy-in among participants;
- acknowledge participants' existing beliefs and practices; and
- make use of an outside facilitator/staff developer. (Richardson, 2003, p. 401).

Participants of the professional development workshop include multiple teachers from the same schools with signed principal support. During the workshop, teachers participate in several collaborative PBL activities to encourage collegiality where they observed, experienced, and wrote PBL lessons. One particular activity geared toward developing buy-in among participants involves watching a veteran PBL facilitator perform a PBL lesson with high school students. After observing PBL in action, workshop facilitators address concerns regarding potential challenges teachers might encounter when implementing PBL curriculum. The discussion reveals that seeing PBL in action provides teachers with confidence to execute the constructivist strategy. Teacher concerns include the following: 1) directing students without giving information, 2) asking the right questions, and 3) using the right resources. In their small groups, teachers develop a one-hour PBL lesson and subsequently teach their lesson to high school students. In the follow-up discussion teachers' concerns include mostly classroom management issues such as: 1) getting students to work in groups, 2) waiting for students to be active learners, 3) assigning roles, and 4) teaching procedures.

Two essential elements of research-based professional development less emphasized during the workshop are long-term follow-up and acknowledgement of participants existing beliefs and practices. After completing the one-week workshop, participants obtain access codes to view on-line PBL lessons and can request materials for teaching the PBL lessons. Follow-up meetings to further participants' understandings and skills after experiencing teaching PBL lessons as part of their classroom routine are not provided. While existing beliefs and practices of participants are not discussed during the workshop, facilitators do address three of the five constructivist learning values. Discussions include the importance of providing students with a role or situating the PBL in a real-world context, which can provide personal relevance. Also included during discussions is the significance of sharing control and student negotiation by providing students with resources to discuss and solve the problem. Critical voice and uncertainty were not addressed during the workshop.

Instructional Lesson Taught by Participants

Teachers participating in this study taught a multiday PBL unit on the classification of kingdoms created with permission from *Robert Whittaker and the Classification of Kingdoms* by Hagen (1996). Prior to beginning the lesson, teachers invited students to think about how living organisms are related and how order can be created out of the chaos of diversity.

Teachers then presented the case by explaining that early taxonomists placed all organisms into either the plant or animal kingdom. However, Herbert Copeland, a biologist, and Robert Whittaker, an ecologist, criticized this system because it did not accurately reflect important biological relationships. Both scientists created different systems for classifying living organisms, which highlights the uncertainty in science. Students share control of the learning environment by investigating the problem and negotiating within their collaborative groups to provide an expert opinion on classification systems while preparing a historical timeline. Opportunities exist for students to exercise their critical voice through directing their own research of the problem.

To establish personal relevance, the first problem introduced students to their roles as taxonomists in 1956 and presented Herbert Copeland's four-kingdom classification scheme and Robert Whittaker's three-kingdom classification system. Copeland organized organisms according to evolutionary relationships, while Whittaker based his original system on an organism's ecological role as producer, consumer, or decomposer. The second problem was set in 1957 after Whittaker immersed himself in the taxonomic literature of unicellular organisms and decided that, similar to Copeland, he needed to add a fourth kingdom. While Whittaker used the same kingdom names (Plantae, Animalia, Fungi, and Protista), the organisms he placed in the Protista kingdom differed from Copeland. In the third problem, students discovered that by 1969 Whittaker became convinced that his Protista kingdom needed to be split into two separate kingdoms, Protista and Monera. The fourth and final problem explains to students Whittaker's struggle with the conflicting demands of portraying a classification system that would reflect important ecological principles while still accurately portraying evolutionary relationships. Students are also introduced to Carl Woese and his 1977 ideas for a six-kingdom classification system. By the end of the unit, students were expected to grasp the challenge of designing a classification system that includes the unusual prokaryotes, reflects important ecological principles, accurately portrays evolutionary relationships, and is convenient to use.

Research Approach

A case study method guided this research by providing an approach to examine four teachers' complex classroom learning environments during PBL instruction. Stake (1995) defines case study as an in-depth inquiry strategy to explore a program, process, or individuals bounded by time and activity. The two weeks participants spent teaching the PBL unit on the classification of kingdoms bind this case study. Creswell (2008) posits the focus of case study as an in-depth analysis using multiple sources of data collection such as documents, interviews, and observations. Using a holistic collective or multiple-case design, Creswell (2008) recommends four cases to provide the appropriate depth for identifying, documenting and exploring the pedagogical practices of teachers.

Selection Criteria

To establish teacher expertise and competence, selection criteria for this study consisted of secondary science teachers with at least three years of teaching experience, degrees in education, and state licensure. The workshop facilitator asked all biology teachers with a valid email address who taught at least one year after participating in the PBL workshop to participate in the study. Having no prior contact with participants, the researcher gained insight into the teaching practices of participants by learning through empathic neutrality in a direct reflective process (Patton, 2001). After learning about the requirements, four teachers meeting the selection constraints with diverse teaching experiences from different school contexts were purposefully selected based on their willingness to participate, approval of their school system, and completion of institutional review board informed consent forms. Participants chose a pseudonym to ensure confidentiality.

Participants and Schools

Each of the four participants represent a case and includes two experienced teachers, Beth and Dana, with five and 16 years of teaching experience, respectively, and two novice teachers, Mark and Emma, with three years of teaching experience. Dana and Emma taught on the block schedule (90 minute classes) at Carson High School, a low performing school where at least 80 percent of the students did not meet grade level expectations. Carson High School serves approximately 870 students, with an ethnically diverse study body of 69% Black, 24% White, 7% Hispanic, and >1% Other. Approximately 53% of the student body is eligible for free or reduced lunch. Beth taught on a regular 50 minute schedule in Nelson High School, a school designated with no special recognition by the state. Nelson High School serves approximately 1,762 students, with an ethnically diverse student body of 51% White, 40% Black, 6% Hispanic, and 3% Asian. Approximately 23% of the student body is eligible for free or reduced lunch. Mark taught regular 50 minute classes at Westfield High School, a school of distinction where at least 80 percent of students met or exceeded grade level expectations. Westfield High School serves approximately 1,943 students, with an ethnic diversity of 73% White, 15% Black, 7% Hispanic, 4% Asian, and >1% Other. Approximately 12% of the student body is eligible for free or reduced lunch.

Data Collection and Analysis

Case study research involves collecting detailed information using a variety of data collection procedures (Creswell, 2008). Data collection consisted of the Constructivist Learning Environment Questionnaire (CLEQ), observations of teachers' practice using the Constructivist Classroom Observation Form (CCOF), and semi-structured interviews. Several measures taken to ensure the reliability of the research include triangulating with multiple sources of evidence, maintaining a chain of evidence during data collection,

pattern-matching, explanation-building, addressing rival explanations and member checking. Member checking involves participants reviewing interview transcripts to confirm accurate conveyance of their beliefs and ideas. To minimize the errors and biases of the study, the researcher used case study protocol and developed a case study database to triangulate data collected (Creswell, 2008).

CLEQ survey

The CLEQ, available in Pecore (2009), served as a basis to identify teachers' beliefs of their classroom environment. The CLEQ is a modification of the Constructivist Learning Environment Survey (CLES) instrument (Taylor, Fraser, & White, 1994) used with permission and modified to enable measurement of the teachers' perception of constructivist approaches to teaching science. The original CLES is a student survey that includes statements (i.e. "In this class, I …") to provide students' perspective on the learning environment. The CLEQ, as a teacher survey, contains reworded statements (i.e. "During PBL lessons, students …") to provide teachers' perspective of the learning environment. The 42-item questionnaire, scored on a five-point Likert scale, requires teachers to (1) almost never, (2) seldom, (3) sometimes, (4) often, or (5) almost always agree with each item statement. The items addressed teacher beliefs of five categories of constructivist learning environments (personal relevance, scientific uncertainty, critical voice, shared control, and student negotiation) and student attitude. A ranking scheme was used to categorize each teacher's alignment with constructivist principles ranging from 7 to 35 points. A score of 7-13 indicated low agreement; a score of 14-20 indicated low intermediate agreement; a score of 21-27 indicated high intermediate agreement, and a score of 28-35 indicated high agreement. Table 1 provides a description and sample item for each constructivist principle.

Participant Observations

To identify classroom culture, the researcher observed teachers for one class period each day the lesson was taught for a total of 10 classroom observations per participant. The desire to record observed teaching practices with respect to constructivist principles necessitated the creation of the CCOF presented in Appendix A (Pecore, 2009). The form is organized to record class information, learning activities, teacher actions/student actions, and notes. The learning activities section is further arranged to notate student engagement, constructivist learning principles, learning director, and pedagogical experiences. Constructivist learning principles are scored on a five point scale for each 10 minute interval with the observer recording the degree (almost always, often, sometimes, seldom, or almost never) to which the classroom environment incorporates aspects of the constructivist principle. The highest daily value of each learning activity is used to calculate alignment of teacher's practice with constructivist principles. To report values consistent with those of the CLEQ, each learning activity's daily observation scores are

Table 1. Constructivist principles, descriptions and sample items for the CLEQ. Description column quoted from Taylor, Fraser & White (1994).

Constructivist Principle	Description	Sample Item
Personal relevance (PR)	Extent to which teachers relate science to students out of school experiences by guiding instruction through meaningful context of students' backgrounds and everyday interests	During PBL lessons, students learn about the world outside of class.
Scientific uncertainty (SU)	Extent to which opportunities are provided for students to experience scientific knowledge as arising from theory dependent inquiry, involving human experience and values, evolving and non-foundational, and culturally and socially determined	During PBL lessons, students learn that views of science have changed over time.
Critical voice (CV)	Extent to which a social climate has been established in which students feel that it is legitimate and beneficial to question the teacher's pedagogical plans and methods to express concerns about any impediments to their learning	During PBL lessons, students are free to express their opinion.
Shared control (SC)	Extent to which students are invited to share with the teacher control of the learning environment, including the articulation of their own learning goals, design and management of their learning activities and determining and applying assessment criteria	During PBL lessons, students help the teacher decide how well their learning is going.
Student negotiation (SN)	Extent to which opportunities exist for students to explain and justify to other students their newly developing ideas and to listen and reflect on the viability of other students' ideas	During PBL lessons, students ask other students to explain their ideas.
Student attitude (SA)	Extent to which students appear to anticipate and view the activities as worthwhile, and the impact of activities on student interest, enjoyment, and understanding	During PBL lessons, the activities increase students' interest in science.

averaged and multiplied by seven. Therefore, a score of 7-13 indicates low constructivist practice; a value of 14-20 indicates low intermediate constructivist practice; a score of 21-27 indicates high intermediate constructivist practice, and a value of 28-35 indicates high constructivist practice

Participant Interviews

Each teacher participated in semi-structured interviews lasting approximately 45 minutes each to elaborate on their views of their classroom environment with respect to constructivist principles. Example questions include the following:

- In what ways was the PBL lesson geared toward student interests?
- What view of science does the PBL lesson help to promote?
- How is the direction of student learning decided?
- In what ways, if any, are students given choices during the PBL lesson?
- Is student-student discussion and reflection incorporated in the PBL lesson? If yes, how? If no, why not?

Data Analysis

The study relied upon a constant comparative method of inductive analysis (Bogdan & Biklen, 2007) for data analysis to code and construct an emerging profile of each teacher's experience with implementing a PBL lesson. Results from the CLEQ were coded using Taylor, Fraser, and White's (1994) guidelines. Field notes recorded during participant observations and individual transcribed interviews were similarly coded. The results informed assertions regarding high school teachers' beliefs and implementation of PBL instruction.

Results

An analysis of survey data from the CLEQ, observations using the CCOF, and semi-structured interviews informed researcher descriptions of the beliefs and practices of participants facilitating the PBL instructional unit. Savery and Duffy's (1995) instructional principles and Taylor, Fraser, and Fisher's (1997) five values of constructivist learning environments —personal relevance, critical voice, uncertainty, shared control, and student negotiation—provide a framework for interpreting the data. The results section provides first a within-case analysis of each case study and second a cross-case analysis of the four case studies. Table 2 presents a comparison summary of individual case study results discussed throughout this section.

Within-Case Analysis

Presentation of within-case analysis is arranged similarly for each teacher participant: Beth, Dana, Emma, and Mark. First, details of the participant's PBL instruction are provided.

Second, each participant's individual CLEQ scores representing beliefs in and observations and interviews representing practices of constructivist learning principles are discussed.

Beth at Nelson High School

Beth maintained most aspects of her normal classroom routine when facilitating the PBL instructional unit. Her teaching strategies included note-taking, reproducible worksheets, bookwork, and traditional laboratory activities. During the PBL lesson sequence, Beth followed the overall process taught in the PBL workshop. However, prior to implementing each problem lesson sequence, she provided students with notes previously prepared for the topic. She also maintained the same textbook readings and worksheets as homework assignments throughout the PBL lesson sequence. Neither the notes nor homework fol-

Table 2. Comparison of participants' beliefs and practices

Constructivist principles	Beth	Dana	Emma	Mark
Mean surveyed beliefs	HI	H	HI	HI
Observed practices	LI	HI	LI	HI
High beliefs	CV	PR, SU, CV, SC, SN	—	—
High intermediate beliefs	PR, SU, SC, SN	—	PR, SU, CV, SN	PR, SU, CV, SN
Low intermediate beliefs	—	—	SC	SC
Low beliefs	—	—	—	—
High practices	—	SC, SN	—	—
High intermediate practices	SU, SC, SN	PR, SU, CV	CV, SC	PR, SU, CV, SC, SN
Low intermediate practices	CV	—	PR, SU, SN	—
Low practices	PR	—	—	—

Key: PR personal relevance, SU scientific uncertainty, CV critical voice, SC shared control, SN student negotiation, SA student attitude, L Low agreement (7-13), LI low intermediate agreement (14-20), HI high intermediate agreement (21-27), and H high agreement (28-35).

lowed the nature of the PBL lesson. An issue Beth mentioned was that she did not modify out-of-class assignments to coincide with the problems presented in the lesson. Beth commented that she should "maybe do the PBL first … and then give notes and bookwork assignments for a few days following teaching the PBL", but remained skeptical about how to do this in the limited time given to her by the county mandated pacing guide. In general, Beth did not execute constructivist instructional principles.

Beth's self-reported mean CLEQ score of 26 indicated she perceived her teaching with high intermediate alignment to constructivist principles. Her scores ranged from a high of 29 in critical voice and student negotiation to a low of 21 in shared control. However, her classroom observations and interview remarks supported a low intermediate agreement to constructivist principles. In practice, Beth promoted student negotiation, scientific uncertainty and shared control with high intermediate agreement scores of 27, 22, and 21 respectively; critical voice with a low intermediate agreement score of 17; and personal relevance with a low agreement score of 13.

For Beth, the problem-solving aspect of PBL lessons should maintain student interests, though she admitted to being worried that a real-world problem would not keep students focused. Classroom observations identified missed opportunities to engage students in personal relevance. Beth remarked that she relied solely on "telling them [students] a story and getting them hooked on something [learning]," thinking this to be "a good way to engage them." Students' playing the role of a taxonomist throughout the PBL lesson was not a main focus for Beth. At one point during the lesson, a student asked about being a taxonomist. Beth responded, "you could be a taxonomist, you have to know species, wish we had time to get into it."

Incidents of making the lesson personally relevant were limited as was students expressing their voices during the PBL lesson. Student negotiation was also low in priority for Beth. She stated,

> I'm sure as it comes down to crunch time and getting through the PBL that this [student-student discussion and reflection] might be what gets thrown out first, but it should be that I might cut down research before I cut down the chance for them to talk about and think about what everybody is reflecting on.

When leading students in sharing information, Beth recorded student responses on the board for the secretary of each group to include in their group's notes. Students were not given the opportunity to discuss or negotiate responses. During the post interview, Beth remarked, "I gave them [students] little time to discuss," as she needed to push on through the lesson to keep pace with the county's guideline.

Students were given application type activities to complete during the PBL, which failed to highlight how science is evolving, provisional, and culturally shaped. When

facilitating activity and research experiences, Beth would guide students to a correct answer by asking lower order (yes/no and either/or) cognitive questions. Beth admitted that sharing control of the learning environment is "sometimes where I have struggled." Her classroom routine was organized and procedural and the classroom culture was one of mostly teacher-directed learning. Beth commented that,

> to a certain extent it [student learning] should be directed by the students, but as the facilitator I need to be a puppet master and direct them that way.… For instance, I need to be very specific about what I want them to do and have things ready for them.

Since there are specific answers that students need to know for the end of course test and not a lot of time to cover all the required material, Beth views PBL as a "tool to push kids beyond the standards that they need to study." Prior to starting the PBL, she purposefully grouped students by directing them to different tables as they first entered the classroom. Beth randomly assigned cooperative learning roles and specific tasks based on student birthdays. Students were not given a choice in managing the learning environment.

Dana at Carson High School

Dana, having fully embraced and implemented PBL instruction for years, taught with a style that incorporated a classroom routine that corresponded well with facilitating PBL. She implemented a color-coded management system that provided structure for student learning known as CHAMP (Conversation, Help, Activity, Movement, Participation) detailing expectations for student behavior in each category depending on the day's activity. Cooperative learning expectations included conversing on topic in student groups only, seeking help when the teacher was in close proximity, completing the activity as assigned, moving as needed for the assignment, and participating actively within student groups. Her teaching process began with a brief focused review of prior knowledge and a highlight of the day's learning outcomes, followed by the group PBL challenge, and closed with recalling the key points of the lesson. The PBL method aligned well with Dana's teaching and enabled her to maintain the flow of the lesson when needing to deviate and insert a 10-minute mini-lecture using her direct instruction protocol. Dana did not think she would change how she taught the lesson for next year, but commented that she would like to focus on the historical development of classification if she could cover the "stuff they [students] need to know" as identified in "the all-important pacing guide."

Dana's self-reported mean CLEQ score of 33 suggested a perceived high agreement with constructivist principles; her category scores ranged from a high of 35 in student negotiation to a low of 29 in shared control. Her classroom observations and interview remarks supported a high intermediate alignment to constructivist principles. In practice,

Dana encouraged a high degree of student negotiation and shared control with scores of 30 and 28, respectively, and a high intermediate degree of critical voice, scientific uncertainty and personal relevance with scores of 26, 23, and 21, respectively. She placed a high degree of importance on using real-world problems that would interest students. Being realistic, Dana remarked that, "Since every problem can't interest every child, you try to hit in the teenage realm of their interest . . . You get to know your kids . . . So you know if it [the problem] is going to spark their [students] interest at least at some point." At different times during the PBL, Dana used the role of students as taxonomist to engage students through personal relevance. She viewed PBL as an instructional strategy for all students stating that PBL helps students to learn that "there are lots of right answers, and still wrong answers, but lots of right possibilities." Dana understood PBL to be "presenting the problem and expecting them [students] to use the resources you've given them to solve it and to take care of it."

For most of the lesson, Dana shared the direction of student learning with students. She commented that once given the problem, students should take ownership over the path taken to solve the problem. By giving students merely enough help to "push through so that they don't get too frustrated and give up," Dana shared the direction of learning with students while encouraging student ownership of their learning. Another way Dana demonstrated sharing control of the learning environment was by having students self-select into cooperative groups.

Student discussion and reflection was an important aspect of PBL for Dana. She stated,

> You have to have it [student-student discussions]. You can't work with a group of people and make decisions if you're not reflecting and discussing. My classroom is arranged so I can do PBL or a lab, so they [students] are in groups of 4 . . . that's their team.

During the majority of the time, students worked collaboratively on the problem, which provided them with opportunities for discussion. Dana developed a good rapport with each student, helping to provide a safe space for students to voice critical attitudes toward the teaching and learning activities. When circling between groups, she honored students' questions by listening, provided a short response and then left the group to continue thinking. Through constant observation, Dana was able to deduce when some students needed support and when other students needed to be refocused. By developing a positive relationship with her students, Dana was able to create a caring learning environment for her students to exercise their critical voice.

Emma at Carson High School

Emma's normal classroom routine lacked organization, procedures, and consistency and exhibited a classroom culture of mostly teacher-directed learning. Emma remarked, "In

most of our lessons, we just tell them what they need to know and practice using that information." After beginning the PBL lesson by introducing the problem to students, she handed out a typed resource packet with hand written comments and underlined words throughout for students to record key terms and definitions. Emma divided her time teaching the lesson between dealing with classroom management issues, working at her desk (i.e. taking attendance, checking e-mail, printing announcements), and interacting with student groups. Emma acknowledged having classroom management issues that interfered with her ability to teach. A few times she closed the lesson by asking students to write what they liked about the day and what they would do to improve their learning. Emma's classroom practice did not align with constructivist instructional principles.

Emma's self-reported mean CLEQ score of 24 indicated a perceived high intermediate agreement with constructivist principles; her scores ranged from 20 in the category of student choice to 33 in critical voice. However, her classroom observations and interview remarks supported low intermediate agreement to constructivist principles. In practice, Emma ranged from promoting a high intermediate degree of critical voice and shared control with scores of 26 and 23, respectively, to a low intermediate degree of student negotiation, personal relevance, and scientific uncertainty with scores of 20, 15, and 15 respectively.

Students' expressing critical voice was clearly evident in Emma's class; however, students negative comments regarding the learning environment were not always received as constructive criticism. At the start of the lesson, students questioned why they were not provided with more group learning instruction as offered in the PBL. Students also questioned the assigned groupings, being told to move to different tables, and not being allowed to eat in class. Expressing one's voice in Emma's class resulted in a power struggle between teacher and student that often ended in disciplinary actions such as being removed from class.

Emma understood PBL to be about "creating a scenario that students can actually imagine themselves in." She thought, "if the situation they [students] are put into is relevant, if they can relate, then it [PBL] can be very engaging for them." For Emma, a real-world problem involved creating a scenario that placed students in a situation just out of high school. Emma was not focused on uncertainty throughout the lesson. She was more concerned with what she thought would be on the state mandated tests. Emma struggled with using reform-based practices as advocated in the PBL workshop and with incorporating aspects of science not explicit in the State's standard course of study.

Emma viewed student discussion and reflection as what naturally occurs when students "work in groups and they have to at least in pairs come up with their answers" and give presentations. She also remarked "I'm not encouraging that [student-student discussion] as much as I should be." During the majority of the PBL, students mostly took turns making decisions and little negotiation between students was observed.

Emma admitted not being confident with instructing PBL lessons feeling a "need to be more in control." When asked who decides the direction of learning, Emma commented how "ideally the students would be using the information that they research in the PBL lesson to determine the end product or what they get out of it." While Emma seemed to grasp the essence of PBL's emphasis on student-directed learning, sharing control by giving students responsibility over their learning through choices was challenging for Emma. She remarked that in spite of "reading a lot in a behavior workshop about how choices are good for students, I have personally not had many choices in my classroom."

Mark at Westfield High School

Mark viewed PBL as an instructional strategy helping all students become "more responsible for their own learning." Having incorporated aspects of PBL from the PBL workshop into his teaching repertoire, Mark maintained a classroom routine compatible for facilitating the PBL instructional unit. He spent the first five minutes of class time facilitating a conversation about his and students' lives outside of class. Mark then facilitated a 10-minute dynamic lecture using the Promethean whiteboard. He maintained students' attention by asking open-ended questions and connecting the material to their interests. Next, he smoothly transitioned students into the PBL sequence. At the close of the lesson, he held a short recap of the day, which often included students sharing what they learned.

Mark's self-reported mean CLEQ score of 23 indicated he perceived his teaching with high intermediate alignment to constructivist principles. His scores ranged from a high of 27 in student negotiation to a low of 18 in shared control. His classroom observations and interview remarks supported a high intermediate alignment to constructivist principles. In practice, Mark promoted all five constructivist principles with high intermediate agreement with scores of 27 for scientific uncertainty and student negotiation, 23 for critical voice, and 25 for personal relevance and shared control.

Mark understood PBL to engage students by providing "relevant scenarios, something they tie to real life situations and their imagination by putting themselves in the shoes of a person that they're not. Wanting to find the information for themselves." For Mark, the real-world aspect of PBL lessons meant providing problems students would find relevant.

Mark's classroom routine was organized and procedural and the classroom culture was one of partially student-directed learning. Mark embraced students' taking ownership of their learning and willingly shared control of the learning environment with students. When possible, he allowed flexibility for students to "go in different directions…and come up with different final products." Student-student discussion and reflection was a priority for Mark. He commented,

> It's one of those pieces of PBL that I've pulled out more independently for a lot of different things. For a lab report students do, I'll have them work on it

> together, give it to another group to make some comments on and give it back to them and let them make some corrections based on the comments from their peers.

Throughout the PBL lesson, students were observed discussing, debating, and negotiating in small group and as a whole class.

Cross-Case Analysis

Stigler and Hiebert (1999) contend that teachers modify features (i.e. physical setting, resources, schedules) to fit within their current system, and the apparent change in surface features does not fundamentally change the nature of instruction. Participants who had an established teaching routine taught the PBL unit to fit within their teaching systems. Three of the four teachers, Beth, Dana, and Mark, used preexisting classroom structures to facilitate the PBL instruction. Emma, not having a consistent classroom routine to modify, was the one teacher who taught the PBL instructional unit without modifying an existing classroom structure. Mark and Dana, having previously modified their classroom teaching to include components of PBL learned during the workshop, were well prepared to facilitate the PBL instructional unit. Mark kept his routine of mini-lectures to students, but geared the notes presented to students on the daily PBL topic. He also incorporated additional activities typical of his instruction, such as viewing organisms being researched under microscopes. Dana used her colored-coded management system to structure student learning, which provided students with behavioral expectations. Both Mark and Dana built in structures that helped them become comfortable with giving control of the learning over to students.

Beth and Emma were less prepared to facilitate the PBL instructional unit. Neither teacher had the classroom structure in place for managing a constructivist classroom. While Beth made surface changes to fit PBL features into her lessons, she made fewer fundamental changes to the nature of her instruction. Beth maintained her notes, textbook readings, worksheets, and homework assignments from previous years of teaching the topic. Thus, her instruction did not flow with the PBL lessons. Emma had not established a classroom culture for cooperative learning and student expectations were not asserted, which resulted in power struggles, misbehavior, and a few students doing the majority of the work. Neither Beth nor Emma were comfortable sharing control of the learning environment with students and had not incorporated a system that provided students with responsibility for learning.

According to data from the CLEQ instrument, the two experienced participants, Dana and Beth, self-reported a slightly higher degree of alignment than the two novice participants, Emma and Mark, with constructivist principles. Dana and Beth reported a mean value of 33 and 26, respectively while Emma and Mark reported a mean value of 24

and 23, respectively. All four participants reported beliefs in the high to high intermediate range. In practice; however, observations and interviews showed constructivist principles to be more represented in Dana and Mark's instruction, than Beth and Emma's teaching.

During the interviews, participants discussed possible obstacles to implementing PBL and mentioned the importance of school administrators. Specifically, Beth felt hampered by the department's weekly quizzes, county mandated pacing guide and end of course tests. Dana saw administrative support as a must for successful implementation of PBL commenting, "administrators need to be OK with noise." Emma, like Beth, remarked that administration's enforcement of the pacing guide and standard course of study imposed obstacles to overcome. Mark, who viewed end of course tests as an obstacle, stated that administrators are "going to judge me by student test scores and by what students, and maybe other teachers, say about me." Other obstacles to implementing PBL mentioned by participants include low student motivation, limited instructional time, lack of establishing a collaborative culture, and week questioning techniques.

In general, Dana and Mark, who aligned higher in practice to constructivist principles, assimilated aspects from the PBL workshop into their teaching system. Beth, who did not align as high in practice to constructivist principles, adopted PBL while maintaining as much of her routine system of teaching as possible. Emma, who aligned lowest in practice to constructivist principles, adopted PBL without assimilating or maintaining aspects of a system of teaching.

Discussion

In theory, PBL aligns with high agreement to constructivist principles (van Berkel & Schmidt, 2000; Savery & Duff, 1995) and the participants in this study believed with high intermediate to high agreement that their PBL unit aligned with constructivist principles. Researchers have posited teacher beliefs towards reform-based learning environments influence teaching practices and beliefs play a critical role with influencing alignment of practice to constructivist learning environments (Czerniak & Lumpe, 1996; Luft 2001). Similarly, teachers use reform-based practices and an investigatory classroom culture if they are more sympathetic towards reform (Supovitz & Turner, 2000). Despite all four participants in this study having beliefs supportive of constructivist learning environments, not all of the teachers aligned as high in practice to constructivist principles when teaching a PBL unit. This suggests other possibilities besides beliefs as potential sources of interference with constructivist teaching practice.

PBL is an instructional design strategy grounded in constructivism where students become willing and active participants in the learning process. As such, classroom culture plays an important role in a teacher's alignment to constructivist principles and effectiveness of practice. Classroom culture refers to the unspoken and often unconscious

assumptions about how both the teacher and students conduct themselves during the learning environment (Glatthorn & Craft-Tripp, 2000). Brown (2005) attributes a classroom culture based on respectful relationships between students and teachers to effective communication. Teachers of this study who aligned higher in practice with constructivist practices, Dana and Mark, had developed a classroom culture consistent with constructivist principles. This study is in line with the thoughts of Sonmez and Lee (2003) who ascribe the effectiveness of PBL, in part, to "the nature of student engagement and the culture of the classroom" (p. 2).

The difference between beliefs and practice could be attributed to accountability measures imposed by school administration. Research studies involving accountability measures such as end of course testing, cite teaching to the test (Shaver, Cuevas, Lee, and Avalos, 2007), eliminating non-tested material (Abrams, Pedulla, & Madaus, 2003), and minimizing student-centered instruction (Bianchini & Kelly, 2003) as concerns (Donnelly & Sadler, 2009). To better reconcile this difference between beliefs and practice, teachers should understand how components of the PBL strategy encourage reform-based constructivist practices and can increase student performance on high-stakes tests by increasing student gains in cognition, development of skills, independent learning, cooperation, and motivation (Chiappetta & Koballa, 2005; Smith, Powell, & Wood, 1995; Sonmez & Lee, 2003; Weller & Karp-Boss, 2007).

The findings of this study are consistent with previous work that demonstrated apparent change in surface features may not fundamentally change the nature of instruction since teachers may simply modify features to fit within their current instructional system (Stigler & Hiebert, 1999). Systems of teaching include factors that influence how teachers teach. Such features could include the physical setting of the classroom, resources such as textbooks, standards, pacing guides, the role of students, and daily school schedules (i.e. 50-minute or 90-minute class times). Due to the constructivist principles inherent in PBL (Savery & Duffy, 1995), the teachers of this study who assimilated the PBL instructional strategy into preexisting constructivist classroom structures facilitated instruction more consistent with reform-based student-centered curriculum.

According to the NSTA (2006), "a high-quality science teacher workforce requires meaningful, ongoing professional development." One key principle cited as constituting quality professional development for science educators is examining practice. Richardson (2003) concurs that professional development needs to be long term with follow-up. Another one of Richardson's (2003) nine characteristics of research-based professional development is acknowledgment of participants' existing beliefs and practices. When offering professional development opportunities for learning a novel constructivist teaching model such as PBL, teachers' current systems of practice need to be both acknowledged and examined. By assisting teachers with assimilating PBL into preexisting routines and being explicit about how the instructional method aligns with constructivist principles,

professional development instructors can best maintain the integrity of instruction so that constructivist principles are encouraged.

Being mindful of methodological limitations is important when considering the findings of a study. This study involves four high school biology teachers conducting one two-week PBL lesson. Since teachers tend to seek out professional development opportunities that are consistent with their pedagogical orientations (Opfer & Pedder, 2011), it is not surprising that results from participants' self-reported CLEQ instrument revealed beliefs that correspond positively to constructivist principles.

An area of future research should reach beyond beliefs and involve studying the impact of a reform-based workshop on teachers' classroom practice. Future research questions should include the following: In what ways do teachers change their classroom practices when teaching reform-based methods or modify reform-based methods to fit their classroom systems, and what effects, if any, do teachers' adaptations have on the integrity of reform-based methods? As a constructivist-based strategy, PBL requires classroom systems that promote students taking ownership of learning. Further investigation of ways in which teachers foster reform-based classroom cultures is warranted. Reform-based teacher workshops should focus not only on a method of instruction, but more importantly on ways teachers might fundamentally change the nature of their instruction in a way that best supports science reform-based curriculum.

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Appendix A

Constructivist Classroom Observation Form (CCOF) developed by John Pecore

Overview

The CCOF was developed by modifying the Differentiated Classroom Observation Scale (DCOS) Protocol developed by Cassady, Speris, Adams, Cross, Dixon, and Pierce (2004). The goal when using the CCOF is to characterize a teacher's classroom learning environment with respect to constructivist learning. The form is divided into three sections: a table for scoring learning activities and behaviors, a chart for describing both teacher and student actions, and a section for writing additional field notes.

Header Information

The header of the form provides a space for recording the name of the teacher and school where the observation is taking place, the observation date, start time, and end time.

Segment Scoring

The form consists of five scoring segments. Each segment may be defined by time like 10 minutes or by event such as introduction, exploration, explanation, or closure portion of the lesson.

- Learning Activity: For each scoring segment, record the instructional activity codes as described in Table A-1. Each segment may have multiple learning activities.
- Student Engagement: In the student engagement row, record the level of student engagement as defined by the percent, as defined in Table A-2, of students that appear to be actively learning/thinking for each segment.
- Constructivist Learning Principles: Using Table A-2, record the degree to which each of the six constructivist learning environment principles are evident during each segment of the observation.
- Learning Direction: In the learning direction row, record for each segment who makes the decisions about the learning activities as defined in Table A-2.
- Pedagogical Experience: Use the final row to record if obstacles, limitations, and/or successes are observed as defined in Table A-3. Record a code in the same box. Provide additional details in the Actions or Notes section.

Scoring Class Information

In the first column record class information such as the class period, the type of class and the number of students working in groups as detailed in Table A-4.

Teacher Student Actions

Use this chart to record the student and associated teacher actions.

Notes

This section can be used to record qualitative field notes during the observation.

Teacher: _____ Observation Date: _____
School: _____ Start Time: _____ End Time: _____

Constructivist Classroom Observation Scale: Scoring Form

			1st 10 min.	2nd 10 min.	3rd 10 min.	4th 10 min.	5th 10 min.
Class Information	Activity						
	Student Engagement		① ② ③ ④ ⑤	① ② ③ ④ ⑤	① ② ③ ④ ⑤	① ② ③ ④ ⑤	① ② ③ ④ ⑤
Period: ___	Constructivist Learning Principles	**PR**	① ② ③ ④ ⑤	① ② ③ ④ ⑤	① ② ③ ④ ⑤	① ② ③ ④ ⑤	① ② ③ ④ ⑤
		SU	① ② ③ ④ ⑤	① ② ③ ④ ⑤	① ② ③ ④ ⑤	① ② ③ ④ ⑤	① ② ③ ④ ⑤
□ R □ H □ I		**CV**	① ② ③ ④ ⑤	① ② ③ ④ ⑤	① ② ③ ④ ⑤	① ② ③ ④ ⑤	① ② ③ ④ ⑤
		SC	① ② ③ ④ ⑤	① ② ③ ④ ⑤	① ② ③ ④ ⑤	① ② ③ ④ ⑤	① ② ③ ④ ⑤
# S/gr: ___		**SN**	① ② ③ ④ ⑤	① ② ③ ④ ⑤	① ② ③ ④ ⑤	① ② ③ ④ ⑤	① ② ③ ④ ⑤
		AS	① ② ③ ④ ⑤	① ② ③ ④ ⑤	① ② ③ ④ ⑤	① ② ③ ④ ⑤	① ② ③ ④ ⑤
	Learning Director		① ② ③ ④ ⑤	① ② ③ ④ ⑤	① ② ③ ④ ⑤	① ② ③ ④ ⑤	① ② ③ ④ ⑤
	Pedagogical Experience		□ O □ L □ S	□ O □ L □ S	□ O □ L □ S	□ O □ L □ S	□ O □ L □ S

Teacher Actions	Student Actions

Notes: _____

Table A-1

Instructional Activity Codes

Instructional Activity	Code	Description
Teacher reads problem	TP	Teacher reads problem to group of students
Students read the problem	SP	Students read the problem in small groups
Student groups	GD	Students in small groups discuss facts, need to know, action plan, and ideas/solutions
Teacher interacting with individual student	TIS	Teacher working with/talking to/helping individual student
Teacher interacting with small group	TIG	Teacher working with/talking to/helping small group of students
Technology use-students	TS	Technology being used by students for related learning activities (e.g., computer)
Other resources use - students	NTS	Other resources provided by teacher for related learning activities (e.g., books; teacher sheets)
Student presentation	SP	Student(s) presenting information to the class (either planned or on-demand task)
Demonstration by teacher	D	Teacher demonstrating a procedure to the class (e.g., how to draw a classification scheme)
Questioning by teacher	Q	Teacher asking question of student(s) in group setting
Student responding	SR	Student(s) answering questions posed by teacher (choral response included)
Manipulative	M	Student(s) working with concrete materials to illustrate abstract concepts (e.g., visual aids)
Seat work - individual	SWI	Student(s) working at desk on academic materials (independently)
Seat work - group based	SWG	Student(s) working at desk on academic materials (groups)
Cooperative learning	CL	Students working in a planned cooperative structure to complete a task.
Technology use - teacher	TT	Technology being used by the teacher for presenting instructional content
Assessment activity	A	Student(s) engaged in a formalized assessment activity (e.g., test; performance)
Teacher directed discussion	TDD	Teacher facilitates a whole class discussion
Teacher lecture	TL	Teacher provides lecture / students take notes
Other	0	List "other" activities

Table A-2

Student Engagement, Learning Environment Principles, & "Learning Director"

These are global ratings for each 10-minute segment. Thus, each segment will have only one rating for each of these domains, the rating that is most representative of that time period for that group.

Student Engagement (active learning/thinking)	Constructivist Learning Principles	"Learning Director"
1 – Low engagement = 20% or fewer of students engaged in learning 3 – Moderate engagement = 21 – 79% of students engaged in learning 5 – High engagement = 80% or more students engaged in learning	PR - Personal Relevance SU - Scientific Uncertainty CV - Critical Voice SC - Shared Control SN - Student Negotiation SA - Student Attitude Ratings are made in each segment following the given scale: 1 – Not evident / negative 3 – Evident / neutral 5 – Well-represented / positive	Who directs the learning, or makes the decisions about the learning activities. Use the following scale for making your segment ratings for the identified groups: 1 – Teacher directs all learning. 2 – Teacher directs most learning. 3 – Teacher and student share learning decisions 4 – Student directs most learning 5 – Student directs all learning

Table A-3

Pedagogical Experience

O – Obstacles = Record specific obstacles encountered L – Limitations = Note specific limitations S – Successes = Record specific successes observed

Table A-4

Class Information

Period: ___ = what period (time of day) the class is taught. R – regular; H – honors; I – inclusion = Type of biology class # S/gr: ___ = Number of students per group