Synthesis Report

Understanding Proficiency in Project-Based Instruction: Interlinking the Perceptions and Experiences of Preservice and In-service Teachers and their Students

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Abstract

This longitudinal mixed method study layers three years of historical preservice teacher data with qualitative descriptive case study of novice teachers at a project-based high school. The study investigates the comparable experiences of preservice and inservice teachers who attended the same teacher preparation program, including a capstone course on project-based instruction (PBI). Additionally, this study seeks to capture the transition in PBI expertise from preservice teaching through third year teaching.

Purpose

This study investigates the comparable experiences of preservice and inservice teachers who attended the same teacher preparation program, including a capstone course on project-based instruction (PBI). Additionally, this study seeks to capture the transition in PBI expertise from preservice teaching through third year teaching.

Theoretical Framework

Project-based instruction (PBI) has deep theoretical traditions starting at the turn of the last century. It began as an extension of the American progressive education movement of the early 1900's with Kirkpatrick's (1918) assertion that education should focus on children engaging in self-directed purposeful inquiry and Dewey's (1938) contention that teachers should guide students in that purposeful inquiry. Vygotsky's (1962) *Social Development Theory* linked social dialog with cognition and formed the basis for the collaborative learning work of Johnson and Johnson (1981) and Slavin (1985).

PBI integrates Dewey's (1938) guided real-world problem solving opportunities with cooperative learning strategies (Johnson & Johnson, 1981; Slavin, 1985) while it addresses national calls for inquiry in science education. PBI has been shown to have benefits for students including increases in science achievement (Geier, et al., 2008; Marx et al., 2004; Schneider, Krajcik, Marx & Soloway, 2002), increased scientific inquiry skills (Baumgartner & Zabin, 2008), and development of a more holistic view of the discipline (Boaler, 2002). However, inquiry methods such as PBI are not widely adopted for a variety of reasons. Despite offering promise, PBI presents unique challenges for teachers and students: including (a) PBI requires deep and flexible teacher content knowledge, (b) PBI requires more effort for both the teacher and students, (c) PBI is time consuming, (d) Classroom management is more difficult in PBI than transmission approaches to instruction, (e) Teachers must provide adequate scaffolding for students to succeed without stifling student investigations, and (f) Students feel more comfortable in traditional classes than PBI (Beck, Czerniak, & Lumpe, 2000; Frank & Barzilai, 2004; Ladewski, Krajcik, & Harvey, 1994; Polman, 2000). Toolin (2004) finds that teachers with strong content and pedagogy backgrounds are more likely to implement projects in their classes than those who lack formal training in education. She also asserts that first year teachers with support structures such as team teaching, one-on-one professional development, and PD workshops become capable of implementing successful PBI units. Berliner (2001) finds that teachers develop competence around their third year of teaching and expertise between their fifth and seventh year of teaching.

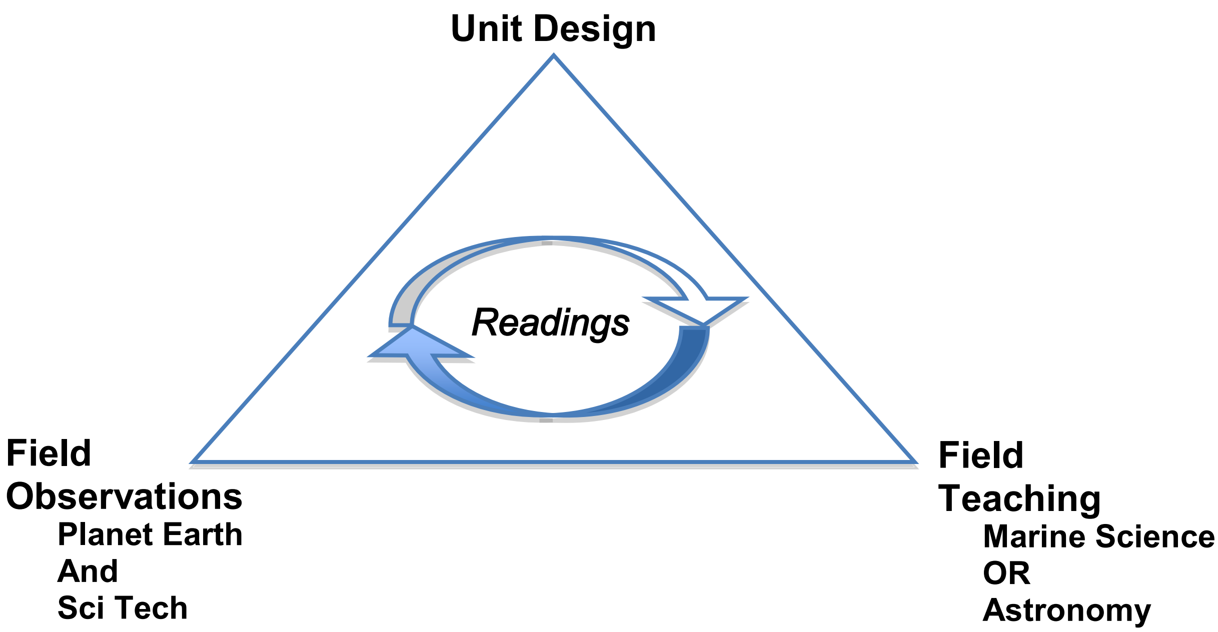
Methodology

This mixed methods longitudinal study consists of two phases. The first phase utilizes three years of preservice teacher data in a mixed methods approach to provide a historical backdrop for the case studies. The rationale for the larger background phase is to contextualize the experiences of the case study participants since only a small number of teachers find employment in schools that use PBI as a policy across all science courses. The second phase employs a qualitative descriptive case study of novice teachers at a project-based high school. The case is defined as the experiences of high school science teachers who are exclusively utilizing PBI. We implemented the study at a technology infused high school that meets the PBI criteria, inviting all science teachers to participate. Luckily, all members of the available population agreed to participate in the study. To ensure internal validity, the study relies on triangulation (Denzin, 1970), member checks (Guba & Lincoln, 1981), repeated observations over the course of the study, participatory modes of research (Merriam & Simpson, 1984), and detailed clarification of the researchers' orientations at the forefront of the study (Merriam, 1988).

Setting and Participants

Preservice teacher preparation program – UTeach. The preservice teacher preparation program primarily serves undergraduates but has an accelerated track for post-baccalaureate students. The program advocates inquiry strategies in all of its courses and culminates with a project-based instruction course prior to student teaching. The project-based instruction course included four key elements: readings about PBI, PBI unit design, observations of established PBI classrooms, and team-teaching a short PBI unit (See Figure 1). The UTeach program graduates about seventy math and science secondary teachers per year.

Figure 1. The relationship between components of the PBI course.



Readings on PBI and Field Observations of PBI. Preservice science teachers read Polman's (2000) account of a seasoned high school teacher who struggled implementing PBI. Mathematics preservice teachers in the same class read Jo Boaler's (2002) comparison of mathematics instruction at two schools — a reform-based school and a traditional school. Students also observed four hours of PBI instruction at a local high school. The PBI classes included *Planet Earth*, an interdisciplinary course on the origins and evolution of the Earth and human impacts on the Earth, and *Science and Technology*, a physical science course modeled after the Massachusetts Institute of Technology Mousetrap Challenge. After each classroom observation, the preservice teachers posted neutral observation reports in online community forums. Class discussions synthesized the readings and observations. Class discussions focused on differing implementations of PBI, the benefits and limitations of PBI, management of PBI environments, and what constitutes PBI. The community forums where students posted observation reflections provided valuable data collection opportunities.

Teaching Experiences. All preservice participants chose either a marine science or astronomy focused teaching experience. The marine science teaching experience option involved two weekend field trips to the University of Texas Marine Sciences Institute located on the coast about 250 miles from Austin. The first field trip was designed to orient preservice teachers to the facilities, coastal environments, and possible teaching topics. At the end of the first field trip, preservice teachers brainstormed ideas and devised a driving question for the next field trip. They spent about a month organizing lessons around that driving question. The second field trip was a joint venture with several high schools from the Austin area. During the second field trip, preservice teachers taught inquiry lessons to the secondary students with the goal of collaboratively addressing the driving question for the trip. For example the driving question for one trip was, “Is the marine environment an opportunity for living organisms to exploit or an obstacle to be overcome?” Lessons taught on the jetty emphasized the challenges of living on a hard surface with pounding surf and tides whereas lessons taught at the salt marsh emphasized adaptations for living in an anaerobic soft substrate with almost no wave action. Culminating lessons encouraged debate about the driving question and human impacts/responsibilities for protecting these environments.

The astronomy teaching experience option also involved two all-day, in-school field trips at a local high school. The driving question, “How can we use mathematics to design and use a Dobsonian telescope?” was provided by the instructor. Preservice teachers built the bases of Dobsonian telescopes and then taught lessons that included defining a parabola, using conic sections to identify the focal length of the primary mirror (Siegel, Dickinson, & Hooper, 2007), discovering the mathematical basis for light reflection on straight and parabolic mirrors, and positioning mirrors and eye-pieces within the telescope tube. Through these lessons, the high school students explored properties of light and parabolas while constructing the rest of the telescope. While this field option primarily targeted preservice mathematics teachers in the course, many preservice science teachers opted for this option.

Curriculum Design. To prepare preservice teachers philosophically and pedagogically for the teamwork aspects of PBI teaching, participants worked in teams of two or three to develop a four-to-six week project-based unit that included a driving question, concept map, project calendar, selected lesson plans, a three-to-five minute anchor video, assessments, grant proposal, resource list, modifications for special needs students, and a short paper introducing the project to their peers. Preservice teachers were strongly encouraged to develop projects that fostered public discourse of socioscientific issues.

Scaffolding Curricular Unit Design. Development of the curriculum unit was highly structured and included the expectation that preservice teachers would revise each part until it met the standard for acceptance. At the beginning of the semester, preservice teachers were given a rubric that identified and defined the unit components (see Figure 2). Toward the end of the semester, professors provided the preservice teachers with an *html* template for the project. The template was a folder with *html* files for each project component. Each *html* file was set up as a table with a navigation bar on the left, a field at the top for the unit title and authors, and a field on the right for the unit component. Preservice teachers converted document and concept map files into *html* or graphics files and pasted them into the fields on the template files. When they completed filling in their *html* templates, we compiled the units into a class CD and posted them online for future reference (http://www.education.txstate.edu/ci/faculty/dickinson/PBI). The template provided uniformity among the projects and made the projects accessible to preservice teachers across semesters and among graduates. Additionally, using a template limited the technology skills required. This put the emphasis on the content rather than the technology. Nonetheless, preservice teachers acquired some technology skills in the process.

Developing High Quality Driving Questions. Several class sessions were devoted to defining PBI, analyzing sample PBI driving questions for quality using Krajcik, Czerniak and Berger’s (2002) five criteria for driving questions, and providing diverse examples of PBI including units from previous semesters. After examining the curriculum of the largest school district in the area, each preservice teacher devised a driving question and an explanation of how the driving question was a good one for the targeted knowledge and skill standard, grade level, and discipline. The preservice teachers posted these on-line for classmates to review. After on-line peer-reviews, the preservice teachers revised their driving questions. Preservice teachers then selected questions from their unit from the list of driving questions that had been generated as a whole. Usually, about one-third of the driving questions were of sufficient quality for the units so preservice teachers typically worked in groups of three to develop their units.

To further assure that the driving questions were sustainable and central to the curriculum, preservice teacher teams developed a concept map of their driving questions. They correlated their maps with state standards and local district curricula to see if the unit was feasible in a school setting (*i.e.,* Did the unit cover sufficient numbers of the state standards to be worthwhile for the amount of time devoted to the unit? A sufficient number of standards would require a pace that allowed for most or all of the state standards to be met in the context of the course).

Developing an Anchor Video for the Unit. Ideally, developing a unit calendar would come next; however, because video cameras and editing equipment were typically in high demand at the end of the semester, preservice teachers developed a short anchor video before developing the rest of the unit. We used *iMovie* to edit and compress the videos because it is very intuitive and has an excellent tutorial. Preservice teachers typically developed one of three types of video: narrated slide show, skit, or video montage. The videos also varied in how much information they provided students. Some videos led students to generate their own questions while others were more prescriptive providing students with a single driving question they would answer.

Unit Calendar, Lesson Plan, and Assessment Development. The next step was developing a unit calendar. The calendar provided another check for sustainability and curricular centrality. If preservice teachers were unable to plan a four-week unit including engaging classroom activities that supported deep understanding of key concepts, then they needed to revise their driving questions. If the driving questions covered too much of the curriculum for the scope of the unit, preservice teachers either scaled back their driving questions or selected a 4-6 week part of the unit as their focus. Each preservice teacher selected two lessons from his/her unit calendar to flesh out in lesson plans. Preservice teachers revised their calendars to include diverse, ongoing assessments derived from *Classroom Assessment Techniques* (Angelo & Cross, 1993).

Inservice teachers at Manor New Tech High School. Three case-study participants in this study were third-year teachers and one was a second-year teacher at Manor New Tech High School. They all completed the UTeach program at the University of Texas at Austin and all have a minimum of a Bachelors degree in science, including the required PBI course described above. The three third-year teachers all completed the UTeach program as postbaccalaureates. The second-year case-study teacher, Laura, completed the UTeach program as an undergraduate. Additionally, during the first year of the study, tenth-grade students (n=12) were interviewed about their perceptions of the PBI environment. Of these twelve students, eight were re-interviewed the following year along with four freshmen.

Data Sources

Historical data come from three years of preservice teacher observations of PBI classrooms (N=142) and a sub-sample from eight years of exit survey data (N=23). Preservice teachers were required to observe four hours of PBI classes at a local high school. The two PBI high school science classes observed were chosen for their contrast with class readings about PBI and with each other. Expert PBI teachers taught both high school PBI science classes. Preservice teachers were instructed to post neutral observations on web forums. These observations were coded by three people for PBI buy-in, degree of overt learning, transferability from observation to practice and comparison with other classrooms. Exit interviews were routinely conducted as part of the preservice teacher program evaluation. These interviews provided a snapshot of preservice teacher perceptions at graduation.

We also have two years of qualitative data to date. Qualitative data sources include (a) artifacts, (b) classroom observations and consultations, (c) individual interviews, and (d) focus groups. Interview data were transcribed and coded.

Analyses

Surveys were descriptively analyzed because of the small sample. Observations were recorded as thick descriptions and coded. We used SPSS (version 15.0) for statistical analyses. The constant comparative method identified emerging themes (Glaser & Strauss, 1967). Formal, time-dependent data collection resides alongside informal, ongoing observations. Individual interviews provide opportunities for member check to validate findings from all data sources. The research team observes participants within high school contexts, with ample prolonged exposure to ensure observations of typical classroom practices. Analyses focus on qualitative cohesiveness as well as differences in experiences across the participants. Individual responses are decontextualized and then grouped together into qualitatively different categories across the group. To protect confidentiality, all campus and participant names are pseudonyms.

Results

Preservice Teacher Observations of PBI Science Classrooms

The three years of analyzed preservice teacher data (N= 142) shows that only a small percentage of preservice teachers expressed buy-in for PBI as an instructional method (25.3% of the observations were rated as high or very high buy-in). Inservice teachers indicated that preservice classroom observations did not give them a feel for how projects flowed. One teacher commented, “I feel like when you come in and you do a snap shot observation, you don’t really get an idea of anything.” This is reflected in the preservice teacher observations where only 23.2% expressed overt learning as a result of observing project based classes. A few preservice teachers (6.3%) reflected on how the classes they observed compared with classes they read about and very few (4.2%) applied what they observed to their future classrooms (See Tables 1 and 2).

Table 1: Degree of buy-in reflected in preservice teacher observations of PBI science classrooms.

	N	Range	Minimum	Maximum	Mean	SD
Degree of Buy-In (1= Low, 5 = High)	142	4	2	5	3.32	0.72

Table 2: Preservice teacher reflections on observations of PBI science classrooms.

	N	Yes	Maybe	No	% Yes
Expressed overt learning	142	33	0	109	23.2
Compared observed classes with ones they read about	142	9	0	133	6.3
Applied what they observed to their future classrooms	142	6	3	133	4.2

Preservice Program Exit Survey Findings

We utilized the exit survey data for a random selection of the eight years of available science preservice teacher data to provide a contextual backdrop to understand the teacher participants' attitudinal changes as they transitioned from preservice to inservice PBI teaching. The capstone PBI course included preservice teachers in mathematics, computer science, and science, but we limited the reported sample to preservice science teachers to align to the inservice teacher case studies. As a whole, the preservice science teachers had significantly higher levels of PBI teaching confidence than the mathematics or computer science teachers (.038). Upon graduation, teachers' PBI teaching confidence was not statistically different from other areas of teaching confidence such as inquiry teaching (1.512), science teaching (2.53), direct teaching (2.53), or teaching confidence (.55). We examined multiple areas of teaching confidence for the entire sample of preservice teachers and exclusively for the preservice science teachers in the sample (see tables 3 and 4).

Table 3. Descriptive Statistics of Preservice Teachers' Teaching Confidence at Time of Graduation

	N	Range	Minimum	Maximum	Mean	SD
Science Teaching Confidence	23	3	2	5	4.35	.935
PBI Teaching Confidence	23	4	1	5	3.57	.945
Direct Teaching Confidence	23	3	2	5	4.22	.850
Inquiry Efficacy	23	3	2	5	3.96	.878
Collaborative Teaching Confidence	23	3	2	5	4.13	.968
Small Group Teaching Confidence	23	3	2	5	3.96	.976
Student Teaching Confidence	23	1	4	5	4.83	.388

Table 4. Descriptive Statistics of Preservice Science Teachers' Teaching Confidence at Time of Graduation

	N	Range	Minimum	Maximum	Mean	SD
Science Teaching Confidence	9	2	3	5	4.44	.726
PBI Teaching Confidence	9	3	2	5	3.56	.882
Inquiry Efficacy	9	2	3	5	3.78	.667
Direct Teaching Confidence	9	1	4	5	4.33	.500
Collaborative Teaching Confidence	9	3	2	5	3.67	.866
Small Group Teaching Confidence	9	3	2	5	3.89	.928
Student Teaching Confidence	9	1	4	5	4.78	.441

Inservice Teacher Case Study Findings.

We uncovered commonalities among the case study inservice teacher participants highlighted in their practice, interviews, and focus groups about why they use PBI, the challenges and benefits of PBI in practice, as well as reflections on their preparation to teach PBI. Additionally, the analyses uncovered four themes across the participants including, (a) *PBI course foundation*, (b) *reasons for implementing PBI*, (c) what not to do, and (d) teacher collaboration.

Reflections on preservice PBI training. All teachers in this study indicated that preservice exposure to PBI was critical for early adoption. According to the inservice teachers whom we interviewed and/or surveyed, the most significant aspects of the preservice PBI training program were development of the PBI unit, production of an anchor video, and use of Angelo and Cross's (1993) *Classroom Assessment Techniques*. Case study inservice teachers kept copies of *Classroom Assessment Techniques* in their classrooms for ready reference and mentioned using it often.

Inservice teachers offered suggestions for making the classroom observations more useful for preservice teachers. They indicated that the preservice teachers who are observing her classes now need more direction to make use of the observations. One teacher stated that the preservice teachers "need to talk to the students, talk to me"–not just sit there passively. Teachers also felt that observing PBI classes required for graduation would make a better case for implementing

PBI than observing elective PBI classes. The inservice teachers felt that showing preservice teachers examples of PBI in core content classes would help convince them that PBI is a valid method for required courses as opposed to just electives. One teacher suggested having preservice teachers observe project presentations as a means to develop the big picture. She noted that preservice teachers who observed her class on presentation days have deeper questions than those who come out while the project is in progress. However, another teacher noted that preservice teachers need to recognize that students are learning throughout the project and the final product is a culmination of ongoing learning as opposed to a report tacked on to the end of a unit.

Teachers responded to aspects of the PBI training coursework that had immediacy to their practice. All in-service participants commented that writing a unit and producing an anchor video were very useful to them. One teacher commented, "I think that I had a really good idea of what good pieces would go into a PBI unit from taking PBI." Other teachers concurred, "The most valuable part was just writing the project. Just having to go through that process." Having interdisciplinary experiences in the PBI course were also viewed as beneficial. "And also the fact that I was paired with a math teacher [in PBI] was great cause then I already had some practice thinking about how math and science go." Teachers also found the process of creating an anchor video to introduce projects useful. One teacher stated, "I think that the idea of an anchor video is something that's really, really super engaging. And they take so much effort but I think that having that in my head as a thing that's a part of a really successful project and doing it before I came here because I was like all right. I've done iMovie and Lord knows I didn't know how to use it when I did that. So having that experience [was key]."

Inservice teacher's reasons for choosing PBI. Teachers in this study actively sought an educational environment that supported their personal philosophies of teaching. Teachers with graduate degrees in science indicated that PBI resembles the work of scientists, "If you don't teach science the discipline, the processes, then you're really not teaching science. A lot of the stuff that I might teach them now might be outdated by the time they're adults. So if they're not learning how to think like a scientist, how to use data to actually make inferences and to come to conclusions….then I have failed." In contrast, the other two teachers emphasized the difference between PBI and how they learned science, "I was miserable in high school - did not see the point - and I was hoping that with the project-based model there would be a point."

Teachers believe PBI causes students to think deeply about content. One teacher commented, "Last year, I heard over and over again, 'This school is hard. I go home with a headache every day,' 'I didn't have to think like this at my other school.'" Another stated, "If you scaffold [PBI] carefully, it can be really intense and it can get really at these misconceptions as opposed to if you did a direct teach, which I sometimes have to do to clarify but, if I were to do everything like that, there'd be, these conversations would be missing from my classroom and I think a lot would be lost."

Importance of collaboration. All teachers commented that collaboration with their peers was necessary for successful project implementation and they all indicated that being forced to collaborate as preservice teachers helped them adopt that strategy. One summarized, "I could not get through a day if I hadn't been a more, really open to collaboration with other teachers and UTeach forced you to do that all the time."

Third year transitions. As teachers transitioned into their third year of teaching, they shifted from focusing on producing units and struggling with PBI as a method to strategically targeting skills they felt would have the most impact on student success.

Two teachers felt that their focus during their first two years of teaching was on being true to the method. One stated, "Last year I was still worried about 'what does PBL mean?' and sticking to it." Both felt comfortable enough with PBI in their third year to begin integrating other methods within their projects. They indicated they were better able to seamlessly integrate labs during their third year and they no longer felt guilty if they need to direct teach concepts.

Two teachers pinpointed rubrics as key to student success in PBI. One focused on aligning her rubrics with state content standards:

> And I get really anal about it to the point that per rubric on the left column, I'll say what the [state standard] is and I really think deeply about proficient and advanced. Is it really demonstrating the skill that is described in that [state standard]? And if that rubric is solid, then I can almost be guaranteed that all of the support materials I'll prepare to get them to satisfy the rubric will be aligned as well.

The other added,

> I think one of the things I tweak a lot now is the unsatisfactory column. Instead of putting, "did not do this, did not do that," I find myself putting mistakes I expect them to make there like "confuses genotype and phenotype." Those are things you can check against. I tell them to make sure they don't do the things in the unsatisfactory column.

One teacher also noted that she was also getting better at assessing students. She stated that she was implementing "more frequent assessments that help me actually adjust what I'm doing. I'm doing better at recognizing what they need." One of the teachers indicated that attaining rigor in her projects was difficult. "Coming from my own high school background and student teaching where it was just worksheets made it really difficult [to achieve rigor]. At the beginning I was just scratching the surface and now I feel like I'm digging deep." Interestingly, teachers who taught courses outside their major field of study indicated that it was difficult initially to come up with long projects saying they "compartmentalized things too much." They both expressed pride at finally implementing several big projects as opposed to lots of little ones. Rich (1993) found that subject matter proficiency was key for expert behavior in novel situations.

Managing student groups was a struggle for all case study teachers even in their third year. One surmised, "I still feel frazzled with the group dynamics – managing the appropriate use of time." Another admitted, "One thing I need to get better at is using their group contracts to make them accountable." Group contracts are written agreements devised by students using a template. The goal of the contracts is to give students guidance about their behavior in the group and to empower students to hold each other accountable. Groups can "fire" unproductive members who then must find another group or work alone. A third teacher concurred, "I lose track of time. We get to the end of the project and haven't had a collaboration evaluation." Even in her third year, one teacher admitted, "I can't picture it in my head. I see groups who use it well and those that don't and I can't figure for the life of me how to tell those who don't [use group contracts well] how to do it."

Teachers also struggled with level of structure needed for students. Many of the teachers indicated feeling guilty if they provided too much structure for students. One teacher noted, "One of the misconceptions in PBI is that you just give the students an entry document and they will work independently. Teachers think they're doing something wrong if that doesn't happen. Really, they're just kids and they need guidance." Another reflected this attitude when she described her perfect project as one in which the students "could do whatever the task was without asking me and know that they were right." Teachers were beginning to realize that they needed to differentiate the level of support for younger students.

> It's almost like there's too much freedom for them at first. It seems like the younger you have them, the more you need to micromanage the process for them or scaffold. You almost have in your mind that you present this project to them and let them go and with the younger kids, it doesn't work. I have in my mind that if I micromanage, I'm doing something wrong. I'm finding with the sophomores that there's more micromanaging that I should be doing.

One teacher suggested aligning project-related skills to increase student success in the PBI environment. "What I would like to do is look at a vertical alignment. By the end of freshman year we want them to be at this point with using the group contract and by the end of sophomore use it."

Student Perceptions of Teacher Practice

Ethnographic Findings. Within one year of opening the PBI-focused students significantly outperformed their peers at the district's other non-PBI focused high school on state science assessments. This trend continued during the second year (See Table 5).

Table 5. Percent of Students Meeting State Science Assessment Standards

	2008			2009		
	PBI High School	Traditional High School	State	PBI High School	Traditional School	State
All Students	80	54	64	86	47	66
African American	63	45	47	81	37	50
Hispanic	70	50	53	81	47	55
White	99	86	81	94	74	82
Economically Disadvantaged	81	47	50	85	45	53

Student Learning Perceptions Findings. We found six main themes among the student interviewees: (1) Students feel successful and like the PBI environment, (2) PBI is harder but more interesting than traditional methods, (3) Gender differences in student perceptions, (4) Students recognize the importance of rubrics for their success, (5) Students recognize the importance of group contracts but also see varying success with implementation of the group contracts, and (5) Many students, particularly freshmen, have difficulty consistently connecting curricular content to real-world practice.

Across all ethnicity and gender strata, all but one of the student respondents indicated that they feel “successful in science class” and “learn a lot” when their teachers utilize PBI instruction (See Table 6). All but one student indicated he/she liked science and four indicated it was their favorite class. Most students who indicated that they were interested in being “more successful in science” also had reflective goals for future science-related achievement. An overwhelming majority recognized the teaching shift to PBI instruction as being “integral” to their “science success,” agreeing that “the hands-on stuff” contributed to science success. Not surprisingly, teacher roles contributed to students’ perceptions of success. Teachers supported student successes by “interacting with students,” instead of “just saying the words and teaching us,” teachers “join you and know where you’re coming from and shows [sic] you different ways on how to get it.”

Table 6. Descriptive Statistics of Study Year 2 Student Perceptions about Project-Based Science

	N	Range	Minimum	Maximum	Mean	Standard Deviation
How much do you like science?	12	5	1	5	4.0	1.1
How much do you learn in science?	12	4	2	5	4.0	0.8
How successful are you in science?	9	2	4	5	4.4	0.5

In keeping with the findings of Frank and Barzilai (2004), the sample of students generally indicated that PBI was “harder” than other methods of science instruction, but was “more engaging” with “more correct answers.” Compared to non-PBI instruction, students found that, “we just pretty much worked out of textbooks. And now [in PBI] we don’t really use our textbooks unless it’s for reference.” Instead, in PBI, “we usually do projects or demonstrations.” Students recalled doing “a lot of worksheets and fill out stuff out of the book” outside of PBI, while PBI classes involved, “doing more labs and more different types of learning styles with our science.” In PBI instruction, students report, “I don’t think we’ve seen a worksheet here.”

All the students’ responses to academic inquiry questions aligned with correct scientific thinking. They overwhelmingly indicated a community approach to solving scientific problems, even shifting from speaking about non-PBI experiences in the first person singular “I” to making a subtle shift to the first person plural “we” when speaking about the PBI approach. Gender differences were most apparent when discussing the group work aspects of PBI (Carlo, Swadi, & Mpofu, 2003). When asked, “Were there any adjustments you had to make as a student to the way science is taught here using PBI?” Males were more direct about the impact of group work in PBI classrooms. Males exclusively perceived group work as being “challenging”. Despite this perceived difficulty of “learning how to work in groups,” some males responded that they now “preferred groups”. Still, most males agreed that they preferred working independently because “you know exactly what you’re doing and you don’t have to rely on anybody else.”

Females tended to enjoy the collaborative nature of the group work (Deter-Schmelz, Kennedy, & Ramsey, 2002), providing observations such as, “The good thing about it [group work] is that you can depend on other people and you can meet new people and it helps our community like a family cause it’s like our house. “ This response was typical for a segment of female participants who used gendered or domestic images and language to describe the group work consistent with Zubair's (2007) findings about how females metaphorically use language. When asked about working independently, females, at times, expressed surprise at the question such as one response, "Independently? I don't like it 'cause we're able to ask other classmates but we don't like independent. I'm not really an independent person." Therefore, while females may have perceived the groups as positive, this structure may also have served to reinforce traditional models of dependency with ascribed gender roles. Male students' responses also revealed some underlying power imbalances attached to PBI group work, such as this male response, "It's kind of complicated because instead of just being in a group of like in a pair, you're with like three other people and the materials; it just gets too many hands in one section of the lab."

In regular instruction classes, males often dominate the discussion and group pairings (Kelly, 1988). This aligned with what male participants offered, highlighting that they liked included "taking leadership". "I tell them we're going to separate it like this. You bring back the materials and we'll study it out and we'll go from there." On the other hand, some females had assertiveness challenges with group work. PBI helped female students have a vehicle to practice balancing their voice within group interaction findings, "You have to know that it's okay to speak out." Providing mixed gender science communities through PBI may help to balance the gender ratio of students who choose STEM majors in higher education. While the group work aspect of PBI created the greatest gender split in the students' responses, most students, regardless of gender, found benefits in both group and independent work saying, "I like doing both. I like working in groups because you get to interact more with other people and you learn from them and you actually get to know more people sometimes. I like working as an individual sometimes because sometimes you're paired up with people that you can't really trust that much because they're not as good as a worker as you might think. But sometimes working by yourself you may get to pick whatever you want to research and you get your research done."

During second year interviews few students mentioned rubrics, however in the third year, many students mentioned rubrics as playing a significant role in their success. One student appreciated the structure provided by rubrics, "we could check everything off that we need to do and everything that we have done." Another student also felt the rubrics made things clear for her. Students also appreciated the increased structure provided by other project assessments in their classes. During focus groups, students indicated they appreciated the increased quizzes and they wrote "I like all the quizzes" on project reflections. One teacher theorized, "Sometimes they think they understand but realize they don't when they take the quiz." A third student indicated that structure helps project groups succeed.

Nearly all students liked working in groups but they viewed group dynamics as a challenge. Most students felt that accountability within the group was difficult to achieve. One student recognized her biggest challenge as "entrusting my grade to other students." A second student identified the group contract as key to her success, however, a third student noted that firing her peers was difficult and she had never done so. Still another student felt the interpersonal aspects of group work were difficult. She felt clear rubrics facilitated development of effective group contracts. "Once we get our rubric, if I understand that, then I know what to put in the group contract…to make the group work together."

Although most upper-class students had no difficulty in identifying real work applications of science, freshmen did. Even though all students provided detailed descriptions of recent class projects, many freshmen could not describe how those projects or the subject area in general related to their every day lives. One student felt "how the global and community fits into it" was the most difficult aspect of PBI. When asked how science relates to the real world, a freshman could not identify any real-world applications of biology even though she aspired to be a paediatrician and gave detailed descriptions of her biology projects.

Significance of the Study

Implications for Teacher Education

Should PBI be taught in an atmosphere of high stakes testing? We think ample evidence supports that PBI should be taught in high stakes testing environments. Although PBI takes more time than traditional methods of instruction, research indicates that PBI students do as well or better on high stakes tests. Schneider, Krajcik, Marx, and Soloway (2002) assert that high school students engaged in PBI outscored the national sample on 44% of NAEP items. Geier, Blumenfeld, Marx, Krajcik, Fishman, Soloway, and Clay-Chambers (2008) found similar results in their study of urban middle school students engaged in PBI. They found that the effects of participation in PBI units at different grade levels were independent and cumulative. Higher levels of participation resulted in higher levels of achievement. In our study, the PBI high school students outperformed their similarly situated peers on state-mandated achievement tests.

What level of exposure to PBI do preservice teachers need? While this study did not specifically explore varying levels of exposure to PBI, teachers in this study indicated that preservice exposure to PBI was critical for early adoption. The PBI course constituted one-sixth of the 18 hours teacher preparation program – a significant investment of time that required sacrificing deep coverage of other important topics such as special needs students, and reading in the content area.

Why bother if adoption is low? Preservice program faculty often debated what number of graduates implementing PBI was indicated to justify the time devoted to a PBI program was great. Faculty felt that universities have an obligation to challenge the status quo even if it means low adoption levels. Inservice teachers adopting PBI serve as cases for future teachers. Van Driel, Beijaard, and Verloop (2001) found that cases provide a powerful tool in reform of teaching practices.

Implications for Practice

The inservice teacher participants repeatedly stated that the best way for them to ensure that project content was aligned to the standards was to start with the standards and work backward. Peer review of projects prior to implementation also serves as a check for centrality as well as providing opportunities for interdisciplinary links. Their use of backwards curriculum design with a detailed rubric for the final project helped them stay focused during the project so that students met state requirements.

PBI goes hand-in-hand with national science standards. It provides a vehicle to posit the standards in everyday practice and, when PBI is implemented with fidelity, the student achievement results show that the standards work. Teachers who regularly utilized PBI did more than achieve science content success; they created classroom learning environments where a normative culture of collaborative science was the typical, everyday experience. Participants in our study clearly indicated that designing projects around state standards was essential for addressing testing requirements. Yet, our findings went beyond testing successes. Our study showed that through deeply embedded PBI preservice instruction and a continued trajectory of inservice PBI teaching that these participants were able to create classroom communities that imitated how science is done in real world in working contexts. The participants used PBI to bridge the gaps between a) theory and public school actions, b) real world science and public school learning, and c) when the standards become *goals* for science education, the standards become *reality* in reflecting actual student achievement. Moreover, our study showed how PBI filled gaps between stated goals and actual student achievements in districts with large pockets of students who were identified with low socioeconomic status, rural, Hispanic, first generation college-bound, and English language learners. A large portion of students surveyed indicated that they will be the first person in their family to graduate with a US high school diploma; yet, like their fellow PBI learners, they held high hopes of studying science beyond high school.

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