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Developing Expertise in Project-Based Science:

A Longitudinal Study of Teacher Development and Student Perceptions

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Defining Project-Based Science: A Contextual History

While Project-Based Science (PBS) has deep theoretical traditions starting at the turn of the last century, it clearly relates to Goals 2000 Objective 4 and the subsequent formation of the National Standards. PBS began as an extension of the American progressive education movement of the early 1900s when Kirkpatrick (1918) asserted that education should center on children engaging in self-directed, purposeful projects. Dewey (1938) concurred that real-world connections were important in the learning process; however, he contended that projects needed to take the form of joint ventures between teachers and children. Vygotsky's (1962) social development theory argued that language and cognition were inextricably linked. This, along with new findings in the cognitive sciences formed the basis of a transition from individual, competitive learning environments to cooperative learning environments (Slavin 1985).

PBS provides a classroom interface that integrates Dewey's real-world problem solving opportunities with Slavin's cooperative learning strategies. We define PBS as "an instructional method using complex, authentic questions to engage students in long-term, in-depth collaborative learning, resulting in a carefully designed product or artifact" (Dickinson and Jackson 2008). Authentic PBS projects have the following characteristics: (a) a driving question or problem scenario that fosters sustained student engagement over weeks or months, (b) content that is central to curricular standards and meaningful to students, (c) collaboration between students and/or students and adults, (d) ongoing assessment of student work, and (e) student-designed investigations (Krajcik, Czerniak, and Berger 2002; Thomas and Mergandoller 2000).

With PBS emphasis on student work products, public presentations, and projects aligned to address community issues, it strongly aligns to and supports Goals 2000 Objective 4, *students will engage intelligently in public discourse and debate about matters of scientific and technological concern* (Krajcik, Czerniak, and Berger 2002; Steinberg 1997). Moreover, research indicates that PBS increases typical student science achievement (Marx et al. 2004), increases scientific inquiry skills (Baumgartner and Zabin 2008), provides students with a more holistic view of the discipline (Boaler 2002), and engages students who struggle in most academic settings (Wurdinger et al. 2007).

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Despite offering promise, PBS presents unique challenges for teachers and students:

- PBS requires deep and flexible teacher content knowledge.
- PBS requires more effort for both the teacher and students.
- PBS is time consuming.
- Classroom management is more difficult in PBS than transmission approaches to instruction.
- Teachers must provide adequate scaffolding for students to succeed without stifling student investigations.
- Students feel more comfortable in traditional classes than PBS (Ladewski, Krajcik, and Harvey 1994; Beck, Czerniak, and Lumpe 2000; Frank and Barzilai 2004).

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 professional development workshops) become capable of implementing successful PBS units. We contend that preservice training in PBS facilitates early faithful implementation of PBS, which in turn provides students with the opportunity to engage in the public discourse and debate advocated in Goals 2000 Objective 4.

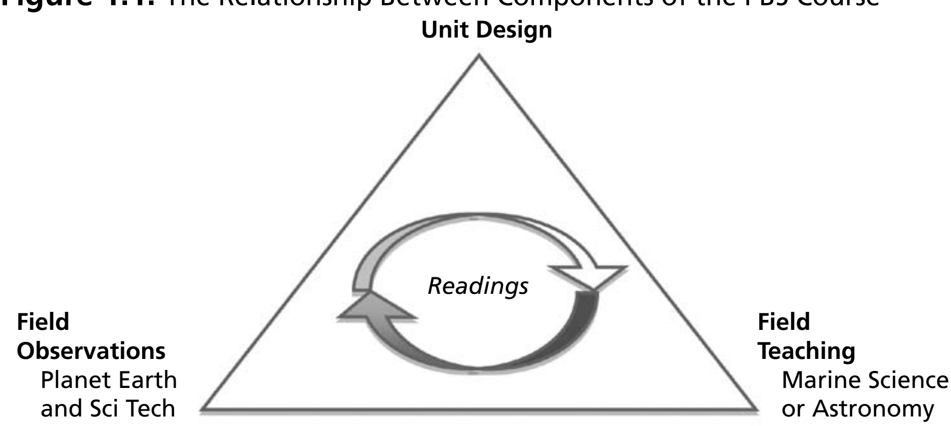
Introduction

This multifaceted study took place over an eight-year time span and covers two educational settings. We report on the participants as both preservice and inservice teachers. Additionally, we report on the learning and perceptions of the secondary students with whom the participants currently teach.

The Preservice University Program Setting

Participants in this study completed an undergraduate teacher preparation program that culminated with a project-based instructional course. This capstone course included four key elements: reading about PBS, making field observations of established PBS classrooms, sharing teaching experiences, and designing a PBS unit (See Figure 1.1).

Figure 1.1. The Relationship Between Components of the PBS Course



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Readings on and Field Observations of PBS

Preservice science teachers read Polman's (2000) account of a seasoned high school teacher who struggled implementing PBS. Students also observed four hours of PBS instruction at a local high school. The PBS 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. Reading reflections and posted observation comments formed the basis for class discussions about the benefits and limitations of PBS, management of PBS environments, and what constitutes PBS. Additionally, these community forums 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 a marine institute located on the coast about 250 miles from the university. 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 identified 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. During this second field trip, preservice teachers taught inquiry lessons to 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 and 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, and Hooper 2008), discovering the mathematical basis for light reflection on straight and parabolic mirrors, and positioning mirrors and eyepieces 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 PBS 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,

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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 1.2). 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 at *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 PBS, analyzing sample PBS driving questions for quality using Krajcik, Czerniak and Berger's (2002) five criteria for driving questions, and providing diverse examples of PBS 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 online for classmates to review. After online 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 concept maps 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 (For example, 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

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Figure 1.2. Sample Rubric for Project-Based Unit

	Points	Accepted (on time and meets standards)	Needs Revision (on-time but needs some revision (-15%)	Needs Conference/ Late (-30%)
Concept Map (2/9) Constructed in Inspiration and saved in HTML format in template file named map.htm	5			
Anchor Video Storyboard (2/11)	5			
Anchor Video (2/21) Quicktime format. Compress as CDROM Med and saved as movie.mov. Compress a second copy as Web small and save as smmovie.mov.	10			
Lesson Plans (2/25) use template from Step II. Save as HTML in files titled lesson1.htm, lesson2.htm, etc.	10			
Resources (2/25) HTML format in template file named resource.htm Web resources (3 annotated URLS per person) Print materials list Supplies (labware, hardware, software, etc.,)	10			
Project Calendar (3/4) HTML format in template file named calendar.htm	5			
Grant (4/15) Use TAPESTRY form. Hard copy and HTML format in template file named grant.htm	10			
Letter to Parents (4/22) HTML format in template file named parents.htm	5			
Assessments (4/22) HTML format in template file named assess.htm	10			
Modifications for Special Needs (4/22)	10			
Introductory Paper (4/29) HTML format in file titled intro.htm Target Audience Project description (1 paragraph) Driving question Overall goals of the project Project objectives Rationale—include theoretical reasons for doing the project Background—1–2 pages of background info (content specific) Standards addressed TEKS National Standards (NCTM or NSTA) National Technology Standards Description of formative and summative assessments including description of final product	10			
Final Presentation (final exam period)	10			
Total Points	100			
All group members participate equally. If not, grades will be weighted appropriately.				

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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, 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 or 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 and Cross 1993).

The Inservice Public School Program Setting

The southwestern U.S. school district used as the field site for inservice teacher observations was, at the time of study, ethnically diverse with the following student population: 69.5% economically disadvantaged, 56% Hispanic, 28% African American, and 14% White. The district had two high schools: one centered on a PBS curriculum and the other utilizing a traditional curriculum. We chose preservice teachers who took teaching positions in a campus where the greatest percentage of time was spent teaching PBS because this setting uniquely allowed us to examine the development of teacher expertise and student outcomes.

PBS in Biology. The inservice biology teachers developed a PBS unit around the driving question, "Are genetically modified foods good or bad?" They constructed a rubric that guided students through aspects of genetics necessary to understand the debate concerning genetically modified organisms. Because students were unaware which side they would represent until a few days before the actual debate, all teams researched both the pros and cons of this issue. Pitting student teams from one class against another added a motivating competitive element.

The inservice biology teachers also developed a PBS unit on speciation that included the driving question, "How would a species adapt to a specific speciation event over thousands of generations?" To begin this project, high school students select a current species and then drew a speciation event out of a hat. Students imagine how their species might adapt in an evolutionary sense. They created a field guide for the new species; they assign it a name, talk about its adaptations, give a phylogeny of where it fits with the previous species, create a dichotomous key to identify it, and sketch a picture of it.

PBS in Astronomy. The astronomy inservice teachers developed a project where students role-play groups of scientists gathering for a conference on misconceptions about the seasons. The groups represent cities at different latitudes so students must share data across groups to look for patterns that will support scientific explanations about the cause of the seasons. The teacher recruits scientific experts from the community to participate in the conference as audience members for student presentations. The experts quiz students and judge student presentations. This motivates students to prepare thoughtful explanations and exceed project requirements.

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Methodology

Participants

This study used a sample of 121 inservice teachers who completed exit surveys at the end of their undergraduate program, 62 inservice teachers who completed longitudinal surveys marking the preservice program's 10-year anniversary, longitudinal preservice teacher observations of two PBS classrooms, interviews and surveys with a random stratified sample of 12 students enrolled in PBS science classes, and in-depth interviews and three years of ethnographic observations of three inservice PBS teachers from their time in an intensive preservice PBS teacher training through their second year of teaching in a PBS-focused high school. The randomly selected student sample was stratified and weighted to emphasize the district's at-risk populations (75% Hispanic, 25% African American, and 17% White).

PBS in Action: A Purposeful In-Depth Look at Three Exemplar PBS Teachers

The teachers chosen as exemplars for the longitudinal ethnographic portion of this study actively sought an educational environment that supported their personal philosophies of teaching. They were recruited from the capstone PBS course by the school principal prior to student teaching. All three teachers included in this qualitative profile of PBS in action completed the program as post-baccalaureates. Stacy (all names pseudonyms) was a non-degree-seeking post-baccalaureate with a BS in environmental science. Christine was earning her masters degree in biology while she completed the program and Jackie was a PhD candidate in Physics. Stacy teaches biology and chemistry, Christine teaches biology and Jackie teaches astronomy and physical science.

Data Sources

Data sources included preservice teacher program exit surveys, preservice teacher program graduate surveys, classroom observations, teacher interviews, student interviews and student surveys. Exit interviews were routinely conducted as part of the preservice teacher program evaluation. These interviews provided a snapshot of preservice teacher perceptions at graduation. To ascertain practicing teacher perceptions, we surveyed program graduates by mail. We observed case study teachers over a period of two years and interviewed them at the end of their second year of teaching. We also surveyed and interviewed high school sophomores at the end of the school's second year to determine their perceptions of the project-based environment.

Analyses

Interview data were transcribed and coded. We analyzed interview and observation data identifying five themes that describe students' perceptions of PBS: (a) success, (b) differences in PBS from other previous science instruction, (c) gender differences, (d) public schooling contexts and barriers to embracing change, and (e) real-life connections. 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.

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Findings

Preservice Teaching Programmatic Findings

According to the inservice teachers whom we interviewed and/or surveyed, the most significant aspects of the preservice PBS training program were development of the PBS unit, production of an anchor video, and use of the *Classroom Assessment Techniques* text. Inservice teachers kept copies of *Classroom Assessment Techniques* in their classrooms for ready reference and mentioned using it often.

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 PBS teaching. The capstone PBS course included preservice teachers in mathematics, computer science, and science, but we limited the reported sample in this chapter to preservice science teachers to align to the inservice teacher case studies. As a whole, the preservice science teachers had significantly higher levels of PBS teaching confidence than the mathematics or computer science teachers (.038). Upon graduation, teachers' PBS 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 1.1 and 1.2).

Table 1.1. Descriptive Statistics of Preservice Teachers' Teaching Confidence at Time of Graduation

	N	Range	Minimum	Maximum	Mean	Std. Deviation
Science Teaching Confidence	23	3	2	5	4.35	.935
PBS 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 1.2. Descriptive Statistics of Preservice Science Teachers' Teaching Confidence at Time of Graduation

	N	Range	Minimum	Maximum	Mean	Std. Deviation
Science Teaching Confidence	9	2	3	5	4.44	.726
PBS 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

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Inservice Teaching

Longitudinal Survey Findings

We mailed program evaluation surveys to a sample (n = 30) representing graduates from 10 years of the program. Two-thirds of the respondents (n = 20) completed the program as undergraduates. The remaining respondents (n = 10) completed the program as post-baccalaureates. The respondents had been teaching an average of 2.45 years (sd = 1.35).

Table 1.3. Demographics of Surveyed Inservice Teachers

Type of School	N
Rural High School	1
Private High School	1
Suburban High School	5
Urban High School	13
Suburban Middle School	2
Urban Middle School	8
Status During Certification Program	
Undergraduate	20
Graduate	10
Number of Years Teaching	
1	9
2	5
3	8
4	4
5	4

Upon entering full-time inservice teaching, 22 of the 30 graduates surveyed by mail indicated they used PBS in their teaching. Even so, many indicated problems with implementing PBS. Most identified the lack of instructional and preparation time for extended projects or fear about classroom management as their chief concern. A third-year teacher related the following:

> Project-based instruction would be wonderful, but you are restricted by time and the curriculum you must get through. Also, it is a bit scary because students could come up with questions that are unanswerable or beyond their abilities. I suppose, you could structure and guide the inquiry, as with the CD-ROM [we] made. I will try it this year.

A first-year high school teacher indicated, "Also, many of my students just waste a large amount of time when I try extended projects." Another issue was pressure to conform to perceived cultural norms. One fourth-year middle school science teacher indicated, "Teachers in the same grade/subject teach in a 'traditional' way and [the] administrators expect grade level/subjects to do the same things so there will not be parent phone calls/concerns." Several of the graduates also

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indicated they would never have known about PBS without having taken the course. One first year science teacher indicated "I try to make PBS as much part of my teaching as possible, and I would not have known how to do that without the PBS course."

Teacher Case Study Findings

School Culture. All three teachers indicated that collaboration with other teachers and support from administrators is key to PBS implementation. Stacy said, "In the program I was in, we had to do things where we worked together and I think the staff, the other science teachers here, we collaborate all the time." Collaboration among teachers helps them refine their projects. Christine said, "I think having people to talk to and having somebody to bounce ideas off of and stuff like that is really, really crucial." The study school uses a critical friends process to review projects before they are implemented. Teachers present their project ideas to their peers who first indicate what they like about the idea. Their peers then identify potential gaps in the project stating what they "wonder" about. For example, teachers may wonder if the project covers sufficient objectives to be worthwhile. Finally, they brainstorm ideas for the project. Christine highlighted the importance of critical peers.

> And that is tremendously helpful. Just because, when you're in by yourself, you don't really have a lot of perspective on your stuff. And, I think getting used to the idea of my stuff is not perfect. It is not my baby. Cause the projects really do start to feel like your baby. And you're like, "Don't touch the baby. I worked really hard on the baby. Stop saying bad things about the baby." You kind of get in a frame of mind of like projects are dynamic. They always change. It's not the baby. The baby can change and that's all right.

Jackie echoed Christine's sentiments.

> I could not get through a day if I hadn't been a more, really open to collaboration with other teachers and [the preservice program] forced you to do that all the time. And that's another huge thing because prior to that I'm an individual learner like I did everything by myself… So it was good to have that practice and to be ready and open-minded to do that because I think if I had been more in that isolated mindset… I probably would've bombed this experience because you can't do it by yourself.

She added that collaboration during her preservice training changed her mindset. "We're always creating our own stuff. And, I never developed the mindset that I'll produce it all myself 'cause we never did."

Christine felt that her discussions with other preservice teachers helped prepare her for the resistance many of her colleagues at other schools face.

> Discussing PBS with my classmates was valuable, because I did not realize how strong my opinion was until I heard people that disagreed with me. And I didn't realize how unusual my opinion was. I assumed everybody would be like, "Awesome! Heck, yeah!"

She added that supportive school culture is important:

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> Here I'm really lucky because everybody who works here is even if maybe they don't love it they're on board with it…. But even my other friends that teach, every now and then will be like, "I just don't know about that." …And you have to be prepared to deal with that. And I think, if I were to ever go work somewhere besides a [PBS] school, I would have to face that.

Jackie also identified cultural resistance as a constraint; although, she chose to focus on student resistance. "Cause everyone's forced to do it, I don't have to play that game of 'why are we doing this here as opposed to the other classes?' Like if I were to try to be PBS at a school where not everyone was doing it, I'd get a lot of resistance."

All three exemplar PBS teachers indicated that repeated exposure to PBS prepares students to succeed in project-based environments. Jackie states,

> The kids are trained now. Collaboration is difficult. You need a lot of practice with it. They're a lot better at managing projects than my freshmen were last year. A lot of issues that just don't come up any more that came up repeatedly [at first].

Stacy also indicated that the students were much better at using project rubrics to guide their progress during the units.

> They have a rubric. And they're a lot better this year at using that kind of like a grocery list is OK; did we do this? Did we do that? Those who were with us last year know that's what's happening.

Time Management. All three teachers identified the time involved with planning and implementing PBS as a concern. Stacy indicated,

> We realized way before spring break oh my gosh to be where we need to be by the end of this week, it is crunch time. So about two weeks ago it was a conscious effort. We shifted from a project to the short like two, three-day problem-based scenarios where they were still getting practice with orally presenting stuff but it wasn't like a two-, three-week project. We just didn't have time.

Jackie expressed concern that school administrators had unrealistic expectations for how quickly teachers could cover required content using PBS. She stated, "And I think they're saying is, 'Oh, you're new teachers, you'll just get faster….Fundamentally, this strategy is slower. There's a limit to how fast we can go if you're going for depth and if you're using this style." Christine asked, "How do you fit this really cool idea you have into three weeks?" Christine identified preparation time as an issue saying;

> But I mean especially with projects, you need long periods of uninterrupted time and it ends up being at home. I knew that but I didn't *know* that. I mean I knew it but I wasn't prepared for exactly how much time it was going to be and how long the hours are.

Christina went on to share that after her first year she established "rules" limiting her time outside of class.

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> I don't work on Saturdays. I used to come home and give myself an hour to an hour and a half where I didn't work. But, now actually I've switched it around. I go home and do everything really fast so that I have free time in the evening. Yeah, you kind of have to make some rules.

Jackie also acknowledged that projects take a long time to develop and they take longer to implement than traditional methods.

All three exemplar teachers indicated that time management is also critical for students engaged in PBS. Stacy advised teachers to have lots of intermediate deadlines to help students pace themselves and monitor their progress. "So all kinds of deadlines like long term, intermediate, and sometimes daily like "show me something!" ... so that I know 'Are you on the right track? Are you even in the ball park? Are you each helping one another?'" Christine and Jackie strongly advocated developing a project calendar and sticking to it. Christine noted,

> Moving deadlines is like death to PBL because then they will never finish and you will get off of your pacing and then you will never catch back up because you know you have to establish the expectation of "we are going to do this and this and this and this week", this and this and this next week, and then we're going to be finished by the end of the next one.

Addressing the Standards. The teachers noted that designing projects around the standards produces units that challenge students and prepare them for state assessments. Christine notes that because PBS takes longer than traditional instruction, it is particularly critical to use instructional time efficiently.

> And so you really do have to sit down and analyze the standards and say, "What is the actual verb here? What do students have to do? Do they need to identify? Do they need to analyze?"... But to really start with the standards and go up as opposed to like how can I make this fit?

Jackie develops the rubric first and lists the standards on the left column of her rubrics. "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 rubrics provide structure and scaffolding for the students. Jackie notes,

> Kids still like to see structure. They still like to have some expectations that you can communicate really clearly, really concisely. So at the end of the day, they're not completely gone and floating in space and not knowing what's going on. There's got to be that balance of choice and still some structure I guess.

Many of the inservice teachers kept and reported using the *Classroom Assessment Techniques* text; whereas, they found Polman's narrative intimidating and not applicable to their daily PBS work.

Contextual Findings

Ethnographic Findings. Within one year of opening, the PBS-focused students significantly outperformed their peers at the district's other non–PBS focused high school on state science assessments. This trend continued during the second year (See Table 1.4).

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Table 1.4. Percent of Students Meeting State Science Assessment Standards

	2008			2009		
	PBS High School	Traditional High School	State	PBS 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. 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 PBS instruction (See Table 1.5). 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 PBS 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 1.5. Descriptive Statistics of 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 PBS was "harder" than other methods of science instruction, but was "more engaging" with "more correct answers." Compared to non-PBS instruction, students found that, "we just pretty much worked out of textbooks. And now [in PBS] we don't really use our textbooks unless it's for reference." Instead, in PBS, "we usually do projects or demonstrations." Students recalled doing "a lot of worksheets and fill out stuff out of the book" outside of PBS, while PBS classes involved, "doing more labs and more different types of learning styles with our science." In PBS instruction, students report, "I don't think we've seen a worksheet here."

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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-PBS experiences in the first-person singular "I" to making a subtle shift to the first person plural "we" when speaking about the PBS approach. Gender differences were most apparent when discussing the group work aspects of PBS (Carlo, Swadi, and Mpofu 2003). When asked, "Were there any adjustments you had to make as a student to the way science is taught here using PBS?" Males were more direct about the impact of group work in PBS 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 (Deeter-Schmelz, Kennedy, and 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 (2008) 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." So 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 PBS 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. 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. PBS 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 PBS may help to balance the gender ratio of students who choose STEM majors in higher education. While the group work aspect of PBS 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."

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Conclusions

Implications for Teacher Education

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

What level of exposure to PBS do preservice teachers need? While this study did not specifically explore varying levels of exposure to PBS, teachers in this study indicated that preservice exposure to PBS was critical for early adoption. Jackie stated,

> I would say from a big picture point of view that I was always in a traditional classroom growing up so the fact that I got exposed to something different and got to see it work is a big deal. Cause, had that intermediate experience not happened, I never would have made the leap to PBS even though now it makes perfect sense.

Stacy concurred. "The PBS class showed me that there was a real viable ALTERNATIVE [sic] to traditional classroom teaching. I was hooked on it once I was in that class." The PBS course constituted one-sixth of the 18-hour 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 if number of graduates implementing justified the time devoted to a PBS 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 PBS 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. Jackie's use of backward curriculum design with a detailed rubric for the final project helped her stay focused during the project so that students met state requirements.

PBS goes hand-in-hand with national science standards. It provides a vehicle to posit the standards in everyday practice and, when PBS is implemented with fidelity, the student achievement results show that the standards work. Teachers who regularly utilized PBS 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

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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 PBS preservice instruction and a continued trajectory of inservice PBS teaching these participants were able to create classroom communities that imitated how science is done in real-world working contexts. The participants used PBS 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 PBS 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 U.S. high school diploma; yet, like their fellow PBS learners, they held high hopes of studying science beyond high school.

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