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# Preservice Teachers' Conceptions and Enactments of Project-Based Instruction

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**Abstract** We present results of an investigation of preservice secondary mathematics and science teachers' conceptions of project-based instruction (PBI) and their enactments of PBI in apprentice (student) teaching. We evaluated their thinking and implementations within a composite framework based on the work of education researchers. We analyzed survey responses, both qualitatively and statistically, from three cohorts of preservice teachers both before and after apprentice teaching. In addition we interviewed and observed a subset of these future teachers. We found that in general the preservice teachers held superficial views of PBI, as compared to the researcher framework. Participants reported time and curriculum restrictions as major barriers; however, teachers for whom enactment of PBI was presented as an explicit goal, and who were given support toward that end, were more likely to enact authentic implementations, regardless of previous reservations about PBI. Without this additional scaffolding, even teachers with high affinity for PBI were unlikely to implement it authentically.

**Keywords** Project based instruction · Preservice teachers · Teacher preparation · Project based learning

## Background and Significance

Today's science educators are called upon to engage their students in authentic, context-rich, activities (Brown et al. 1989) and inquiry focused on "questions generated from student experiences" and "real phenomena" (National Research Council 1996, p. 31). Project-based instruction (PBI) focuses on an authentic task as a vehicle for learning (Kliebard 1995). During the past few decades, PBI has enjoyed a resurgence, in which implementers have sought to address concerns that the method is too concentrated on students' immediate interests rather than on future coursework and employment (Krajcik et al. 1999; Polman 2000a).

Project-based instruction centers on an authentic task but is distinguished from other forms of inductive learning by its focus on the creation of a product, often a report detailing the student's response to a driving question, as a driver for learning (Prince and Felder 2006). A recent development in PBI is a shift in focus from students' immediate interests toward supporting long-term learning goals. Barron et al. (1998) described the challenges of implementing PBI and presented four design principles that reflect this emphasis on broader learning goals: (a) defining learning-appropriate goals that lead to deep understanding, (b) providing scaffolds, (c) providing opportunities for self-assessment and revision, and (d) developing social structures that promote participation and a sense of agency. The first two are aimed primarily at developing content knowledge, the second two at general educational skills.

Many studies have demonstrated the efficacy of PBI in both science and mathematics (Boaler 2002; Krajcik et al. 1998; Lehrer et al. 2001, Petrosino et al. 2003), especially in cases where the instruction tended to include the elements prescribed by Barron et al. (1998). However, with some notable exceptions, little work has concentrated on preservice teachers' learning of PBI. Windschitl and Thompson (2006) reported on preservice, secondary-level, science teachers' engagement in project-based learning, but focused primarily on their development, use, and understanding of

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models in the course of doing projects and whether they planned to invoke the modeling paradigm explicitly in their own classrooms in the future.

Likewise, little is known about how novice teachers, apprentice (student) teachers in particular, implement PBI and the challenges and benefits they encounter in doing so. An extensive review of literature found that new science teachers face many challenges in understanding and implementing effective instructional strategies, but none of the studies included in the review dealt explicitly with PBI (Davis et al. 2006). Polman (2000b) reported issues that arose as an experienced teacher implemented PBI in a high school earth science classroom: ambiguity and risk of unfamiliar, open-ended practices; students' adherence to transmission epistemology; students' perception of time available for a task; and the limited time available to the teacher. He concluded, "The promise of projects in schools will only be realized when educators acknowledge and deal effectively with the realities of their problems as well as their potential benefits" (Polman 2000b, p. 12).

Our study was designed to expand our understanding of what preservice teachers gain from professional development concerning PBI, and how their attitudes toward PBI influence whether and how they implement it in their own classrooms, in particular as student teachers. As such, it is a limited step toward addressing the need for longitudinal evidence on the effectiveness of particular elements of teacher preparation programs and toward understanding the transitions between different phases of professional development (Windschitl 2005), specifically the transition from coursework to apprentice teaching. Understanding how experience with reform pedagogies in professional development courses translates into practice in the classrooms of novice teachers has become more relevant in light of legislation emphasizing accountability systems and testing, which may have the inadvertent consequence of privileging certain pedagogies over others. This leads to challenges in terms of curriculum implementation, planning, and assessment, all of which interact in complex dynamics when attempting to forge sites for apprentice teachers (ATs) to hone their craft under the guidance of practicing mentor teachers.

As a framework for interpreting our students' conceptions of PBI, we first consider conceptions of PBI as articulated by science educators who specialize in this area (Barron et al. 1998; Polman 2000a; Singer et al. 2000; Petrosino n.d.; Linn et al. 2003; WISE n.d.). Identifying the definitive components of PBI is not straightforward, as the instruction given this label can vary widely. In our approach, we identified major research-based instantiations of PBI that have been documented in peer-reviewed literature. As might be expected, essential elements were varied, but there was considerable overlap. Common elements were: (a) a driving question; (b) a tangible product; (c) an investigation (d) use of cognitive tools; (e) collaboration (f) assessments; (g) scaffolding; and (h) length. Table 1 summarizes the essential elements as described by each program.

With an overarching goal of informing our preservice teacher preparation in PBI, we were interested in finding out how our students viewed PBI after coursework in the subject, and how those views affected whether and how they went on to implement PBI as ATs (student teachers) in their own classrooms. We were also interested in discovering what these preservice teachers perceived as likely barriers to the implementation of PBI, what barriers they actually encountered if implementing PBI, and how those experiences changed their views of PBI. The goal was to provide programmatic support to these beginning teachers. Our study was guided by research questions in three broad areas:

1. Preservice teachers' conceptions of PBI:

- What do preservice teachers in our secondary science and math preparation program identify as the key elements of PBI?
- How do their descriptions align with the views of education researchers who have developed this method?
- Do their descriptions change as a result of the student teaching experience?

2. Perceived efficacy of PBI:

- What do these preservice teachers perceive and report as barriers or drawbacks to implementation of PBI?
- How do these preservice teachers perceive the efficacy of PBI with regard to the stated learning goals in the classrooms where they were planning to teach?
- Do these perceptions change as a result of the apprentice teaching experience?

3. Implementation of PBI:

- Do preservice teachers (ATs) implement PBI in their own classrooms during apprentice (student) teaching?
- If so, what do their implementations look like?
- Finally, how do their perceptions of PBI relate to whether and how they implement PBI as ATs?

## Method

Prior to the start of research, a protocol describing the intended study was submitted to, and approved by, the Institutional Review Board of the large research university where the authors are faculty members and where all the participants were enrolled in teacher certification coursework. The participants were drawn from three cohorts of

**Table 1** Key elements of research-based instantiations of PBI

| Source | Driving question | Learner product | Investigation | Assessment | Tools | Collaboration | Scaffolding | Length |
|---|---|---|---|---|---|---|---|---|
| Barron et al.[a] | Connects activities and underlying concepts | Tangible, real world outcome | Complex inquiry | Frequent formative, self assessment and revision | SMART tools | Collaborative activity | Simulated, constrained problems, contrasting cases, social organization to promote agency | Extended |
| CoVis[b] | Open-ended questions | New knowledge or artifacts | Authentic practice, learn by doing | Reflect principles | Collaboration & visualization | Access to scientist mentors, individual or group | Seeding inquiry with powerful ideas | Long-term |
| PBS[c] | Broad, authentic open-ended, authentic. Encompass worthwhile science content | Artifact or product that represents response to driving question | Sustained, situated in life of student. Students gather, analyze data; draw, share, support conclusions | | Learning technologies mirror those used by scientists | Learning communities, including more knowledgeable community members | Teacher (benchmark lessons), learning materials, technology | Relatively long term |
| Petrosino[d] | Driving, Real world problem, multiple content areas | Requires culminating product | Active investigation, learn concepts, apply info, represent knowledge in multiple ways | | Cognitive tools | Learning community | | |
| WISE[e] | Provided by web site | | Accessible, independent activities, require sustained reasoning | Online assessments | Computer tools for visualization, modeling | Online communities | Reflection notes, online discussions, online support, hints | About a week |

[a] Barron et al. (1998)

[b] http://www.covis.northwestern.edu

[c] http://www.umich.edu/~pbsgroup/whatPBS.html

[d] http://college.hmco.com/education/pbl/background.html

[e] http://wise.berkeley.edu/pages/about.php

preservice, secondary-level, science and mathematics teachers who were engaged in apprentice (student) teaching at the time of the study. Approximately half of these future teachers were being certified to teach science of some kind and half to teach mathematics, the majority at the high school level but some also in middle school. All had previously completed a professional development course in PBI as part of the required sequence of courses for certification.[1] During this course, students developed an extensive PBI unit as part of course requirements. The first two cohorts were from the same year. In that year there was an acknowledged effort on the part of the teacher preparation program staff to coordinate the PBI course and Apprentice Teaching course, in particular to facilitate and encourage the implementation of units developed in the PBI course as part of the AT experience. Due to conditions in some of the precollege classrooms where ATs were placed, it was not possible to make this an absolute requirement, but efforts were made to facilitate implementation of these units where possible. In the first cohort all ATs attended a seminar on implementing PBI during apprentice teaching. ATs in Cohort 2 were offered the opportunity to work with their prospective mentor teacher as they designed their PBI units in the PBI course—although none of those interviewed for this study actually did so.

The third cohort was from another year. Cohort 3 was required to design a PBI unit in the PBI class, but program staff did not encourage implementation of a PBI unit during apprentice teaching. All three cohorts were required to submit a portfolio, including a unit of lesson plans. Preservice teachers often submitted the unit they had designed in the PBI course. Acceptance of the portfolio was a requirement for certification.

Preservice teachers in all three cohorts were informed that the ultimate goal of the study was to improve the teacher preparation program in which they were enrolled, particularly with regard to PBI, but they were not given details of the research questions. They were informed that participation was voluntary, and informed consent was obtained from all those who volunteered to participate.

In order to determine how these preservice teachers conceptualized PBI, and how they perceived its efficacy with regard to learning objectives, a survey (see "Appendix A") was developed and administered to volunteers just before they started apprentice teaching. To determine whether the AT experience had any effect on their thinking, the same survey was administered at the end of the apprentice teaching semester. A total of 79 preservice teachers responded to the presurvey, 65 of whom also responded to the postsurvey. In addition, five individuals who did not respond to the presurvey responded to the postsurvey, for a total of 70.

The survey consisted of both Likert-scale and open-ended items (see "Appendix A"). Each Likert-scale item presented an evaluative statement about PBI paired with an implication for classroom instruction, such as, "PBI represents best practices in secondary math and science instruction; all instruction should be done in this format." Thus, agreeing with a statement required students to endorse both a view of PBI and its consequences for the classroom. Students were asked to rate their agreement or disagreement with each statement. Likert-scale items were analyzed quantitatively using a statistics package (SPSS). Respondents without both pre- and postsurveys were omitted from the statistical analysis.

For each AT, an affinity score for PBI was calculated based on how much the individual agreed or disagreed with the Likert-scale statements from the survey. There were six statements, two that were positive about PBI as a teaching method, two that were negative, and two that represented a more balanced view. Responses to the individual statements were combined to create a composite affinity score for PBI, from 0, indicating a complete lack of belief in the efficacy of the method, to 12, indicating the highest enthusiasm.

The open-ended questions asked students to describe what they perceived as the critical elements of PBI, what they perceived as drawbacks to PBI, and either their plans for PBI (presurvey) or their implementation of PBI (postsurvey). Open-ended responses were coded according to themes. At least two independent coders categorized each open-ended response, with typically a 70–80% agreement between independently generated codes. Codes were then consolidated and standardized, and the final code assigned to each response was negotiated between the raters. Codes were recorded in a spreadsheet and frequencies were determined based on the entries.

To gain more insight into the nature of instruction in the cases where the ATs felt that they had implemented PBI, at least in part, and into the reasons why they did or did not implement PBI during their apprentice teaching semester, all respondents to the survey were invited to be interviewed about their implementation of PBI in apprentice teaching. They were assured that the intent of the interviews was simply to inform the design of the preparation program and that their responses would not affect their status in the program in any way and would not be revealed to any of their instructors. All volunteers for whom a suitable interview time could be arranged ($N = 17$) were interviewed. They were roughly equally distributed among the three cohorts, representing 10–20% of each cohort. Those who were interviewed were given token compensation for their time in the interview. The interviews were conducted

[1] Two of the participants were taking the course concurrently with the study.

by the authors and graduate students working under their supervision. Interviews followed a flow chart indicating a course of questions for different response options and allowing latitude for interviewers to follow up new threads that arose in the interview (see "Appendix C"). All interviews were audio recorded and transcribed.

Classroom observations, when available, were used to aid in interpreting the interview and survey results. Collected artifacts included lesson plans, student handouts, and in some cases video of implementation. Field notes during each observation provided detailed descriptions of the activities, patterns of student engagement and participation, and any assessments of learning outcomes.

The interviews, observations, and artifacts were used to characterize the preservice teachers' implementation of PBI in the classroom. Implementations were assigned a score based on a rubric developed by the authors (see "Appendix B"). Two independent evaluators used interview transcripts, artifacts, and observation field notes to rank each implementation on a three-point scale according to each of seven elements: (a) driving question; (b) tangible product; (c) investigation; (d) use of cognitive tools; (e) collaborative nature of the activity; (f) the nature of assessments for the task; and (g) the scaffolding provided for the task. Because of time constraints imposed by the apprentice teaching context, we did not evaluate the final key element identified by education researchers, i.e., length. The ATs only taught completely autonomously for 6 weeks, and were required to meld with their mentor teacher's curriculum at the beginning and end of that time. Therefore the range of reported project lengths only varied from a few days to a couple of weeks, the lower end of the length range considered optimal by experts.

The independent scoring for each of the components was then compared, and any discrepancies were discussed and final scores negotiated. The scores for the seven individual elements were then averaged to create a composite implementation score.

## Results

### Preservice Teachers' Conceptions of PBI

What did preservice teachers in our secondary science and math preparation program identify as the key elements of PBI, and how did their descriptions align with the views of education researchers who have developed this method? How did their descriptions change as a result of the apprentice teaching experience?

The first question on our survey ("What do you consider to be the key elements of PBI? In other words, how would you recognize PBI in a secondary math or science classroom?") addressed the first research question explicitly. Table 2 lists all the codes that were generated by responses from more than one preservice teacher in any cohort, along with the percentage of responses citing that code in the pre-survey (prior to apprentice teaching) and the post-survey (after apprentice teaching). As some respondents listed more than one key element, they were assigned more than one code, and responses that were only given by a single respondent are not included. Thus, the percentages do not necessarily add to 100%.

**Table 2** Key elements of project-based instruction: percentage of responses

| Response | Presurvey (%) | Postsurvey (%) |
|---|---|---|
| Projects | 34 | 44 |
| Discovery, inquiry | 32 | 39 |
| Group work | 25 | 17 |
| Long term | 25 | 6 |
| Teacher behavior | 18 | 29 |
| Student driven | 18 | 36 |
| Theme/unit | 16 | 11 |
| Research | 11 | 3 |
| Authentic, real-life task | 10 | 7 |
| Driving question | 9 | 11 |
| Scaffolding | 9 | 3 |
| Product | 8 | 7 |
| Student interest | 5 | 7 |
| Open-ended | 5 | 6 |
| Assessment | 4 | 7 |

As can be seen in Table 2, the most common description for PBI given prior to apprentice teaching (34% of responses) was simply that it involved something labeled as a "project," with no qualifications about the nature of the project or how it would be implemented. This was followed closely by descriptions indicating that PBI involved inquiry or discovery learning (32% of respondents), group work (25%), or involved an extended time period (25%). The next most commonly listed attributes were descriptions of how a teacher should behave in PBI (i.e., not lecturing, 18%), that the work should be student driven (also 18%), and that there should be a "unit," a series of lessons characterized by a theme (16% of respondents). Students did not indicate how this theme should be used to enhance instruction or how it differed from the label of a curriculum unit, as in the standard curriculum unit on DNA or on quadratic equations.

In comparing these student characterizations with those of science educators who specialize in this area (Table 1), students tended to focus more on superficial aspects of PBI than did the experts. For example, students focused on the existence of something called a "project" and the length of the activity, rather than what a project should consist of, or why an extended time period is required and how it should be used. Only 9% of students felt that a driving question was essential and only 8% felt that a tangible product was necessary, whereas experts identify both of these as key components. Students agreed with experts that PBI should involve hands-on, discovery learning, but fewer than 20% went on to align with experts in stating that this also should be student driven and involve a complex task. Collaborative activity, a critical element in the expert framework, was only mentioned by one-fourth of the preservice teachers who responded to the survey, as noted above. Scaffolding and formative assessment, also critical for PBI instruction (Barron et al. 1998), were mentioned by fewer than 10% of respondents. The use of cognitive tools, the final element of the expert description, was not mentioned at all.

These descriptions of PBI were fairly stable from the beginning to the end of the apprentice teaching experience, as can been seen from Table 2. The top two characterizations, project and inquiry/discovery, actually increased in frequency from the pretest to the posttest, as did descriptions of PBI as student centered and characterizations involving teacher behavior (not lecturing or acting as a guide, for example). The most dramatic change was the decrease in responses describing PBI as involving an extended time period. This decrease was consistent within each of the cohorts as well as in the group as a whole. As noted above, ATs were constrained to implement PBI on shorter time scales than in the books and articles they had read in the PBI class; this may have contributed to their perception that an extended time period was not such an essential element of PBI.

## Barriers to Implementation of PBI

What did preservice teachers perceive as barriers or drawbacks to implementation of PBI? Another question on the pre- and postsurveys asked the preservice teachers to describe what they saw as possible barriers to implementing their plans for PBI (Question 5 in "Appendix A"). Table 3 lists the most common responses, along with the percentage of surveys that listed each of them. Again, the percentages do not necessarily sum to 100%.

The most common barriers on the presurvey were inadequate time to implement PBI, lack of initiative or discipline on the part of precollege students, and curriculum specifications by the department or school, all of which were cited by more than one-third of the ATs. These were followed by resource limitations, state testing requirements, school culture, and mandates from cooperating teachers, all cited by 10% or more of the responding ATs. Some ATs (fewer than 10%) also cited "PBI won't work," objections from parents, their own lack of experience, and the difficulty of designing PBI curriculum as barriers to PBI implementation. Responses were very similar on the survey given after apprentice teaching; students, time, and a specified curriculum were once again the most commonly listed barriers. The perception of state testing requirements and school culture as barriers increased slightly, whereas all the other perceived barriers were cited with less frequency on the postsurvey. Notably, the notion that PBI simply would not work was not listed as a barrier to implementation by any AT on the postsurvey.

**Table 3** Possible barriers to implementing project-based instruction: percentage of responses

| Barrier | Presurvey (%) | Postsurvey (%) |
|---|---|---|
| Time | 37 | 30 |
| (High school) students | 37 | 34 |
| Specified curriculum | 32 | 21 |
| Resources | 15 | 11 |
| State testing requirements | 14 | 15 |
| School culture | 10 | 13 |
| Cooperating teacher | 10 | 4 |
| Policy/administration | 9 | 6 |
| Project-based instruction won't work | 8 | 0 |
| Parents | 8 | 2 |
| Lack of experience | 6 | 2 |
| Difficulty of curriculum design | 6 | 4 |

## Perceived Efficacy of PBI

How did these preservice teachers perceive the efficacy of PBI with regard to the stated learning goals in the classrooms where they were planning to teach? As described above, we computed an affinity score for each preservice teacher, using responses from the pre- and postsurvey characterizing the respondents' belief in the efficacy of PBI. Ranked agreements with statements 2a and 2b from the survey (from 1 to 4 for strongly disagree to strongly agree, see "Appendix A") were summed as the positive PBI score for each survey, likewise statements 2c and 2d as neutral PBI, and statements 2e and 2f as negative PBI. Positive scores had a possible range of 2–8, as did negative scores. We computed the composite score as the difference between the positive-PBI and the negative-PBI scores so that the composite score had a possible range of −6–6. We added 6 to all the composite scores, shifting the possible range from 0 to 12 for the convenience of the statistical analysis. We performed initial analyses that showed no significant effect of cohort (i.e., the three cohorts were not significantly different on their affinity scores). All other analyses, therefore, were performed without this factor. A 2 × 3 repeated-measures analysis of variance (ANOVA) was performed on the composite affinity scores. There were two between-subjects factors: time (pre *vs.* post) and statement type (positive-PBI, neutral-PBI, and negative-PBI). No significant difference between pre- and posttests was found.

There was a significant difference between the positive-PBI, neutral-PBI, and negative-PBI scores, $F(2, 122) = 126.68$, $\text{MSE} = 1.62$, $p < 0.001$. Thus, the respondents as a group viewed these three groups of statements as conveying distinctly different sentiments, interpreting them as we had intended.

The lowest affinity score for any student in either cohort on the presurvey, on a scale from 0 to 12, was a 3 and the highest a 12. However, a majority of the students (77%) fell in the medium affinity category, with scores from 5 to 8. Twenty-three percent of responses fell in the highest category, with scores from 9 to 12. The average score was 7.4 with a standard deviation of 1.6, indicating that on average the respondents felt more positive toward PBI than negative. Affinity scores were also calculated for the postsurvey responses and changed little on average. The average postsurvey score was 7.2 with a standard deviation of 1.7. The highest postsurvey score was a 10 and the lowest a 4, coinciding with the very slight shift in the average toward more neutral responses.

## Implementation of PBI

Information regarding how the ATs implemented PBI (if at all) came from self-reports on the postsurvey; interviews; and, in a few cases, actual classroom observations. In response to the postsurvey question, nearly half of the respondents, 35 out of 71, said that they had implemented PBI minimally or not at all. Slightly more than 10% of the ATs who responded said that their students did a project of some kind, and another 10% described a design project they assigned to their students, in which a product of some kind was required. Nine percent of the respondents simply said that their students had engaged in group work of some kind, and 7% described having had their students use multiple sources to gather information. The other most common responses were having students engage in inquiry, assigning student-centered activities, and having a unit as part of the curriculum (6% each). Four percent of respondents indicated that the only PBI they had implemented was to have students do laboratory work. Thus, the majority of students did not implement all the seven elements, by their own report, and nearly half did not report any part of their apprentice teaching experience as being PBI.

Among the interviewed students, one AT (who apprentice taught in a 9th grade biology classroom) reported no implementation due to constraints of the teaching environment. The other 16 reported various levels of project implementation. Table 4 lists the driving questions or tasks, descriptions of what the projects entailed for the high school students, mathematics or science learning goals, whether the project involved collaboration, and the approximate length. As seen in Table 4, about half of the projects were of 1 week or less in duration and could not be considered the type of extended inquiry required for full implementation of PBI. The math and science was clearly evident in these projects, but the directing influence of the classroom students was not always at the forefront. Neither was the broader goal of "doing with understanding" (Barron et al. 1998, p. 274) always in evidence.

Composite implementation scores were calculated for the ATs who were interviewed, as described in the Method section. The AT who reported no implementation received an implementation score of 0. Of those who reported that they implemented PBI, implementation scores ranged from 0.7 to 2.8 (very nearly completely authentic implementation, according to the expert rubric) with a standard deviation of 0.5. In general, very few individual elements were rated as a 3, or full implementation. The largest group of implementations was rated between minimal and moderate (nine out of those interviewed). Seven implementations were rated between moderate and full, although all but one of those were closer to moderate. One implementation was rated as less than minimal.

Thus, as might be expected of first-time teachers, the ATs did not, in general, implement PBI at a level that would be consistent with an authentic implementation, as described by education researchers specializing in PBI. In large part, the preservice teachers we interviewed agreed with this assessment. In their postimplementation interviews, some expressed reservations about whether they had implemented PBI authentically, describing their instruction as "not as pure project-based as we possibly learned," "it wasn't how we were kind of taught to do things in PBI," "it wasn't project-based, like, I guess that there was no driving question," and "just a little different than what I had been shown." The preservice teachers gave various reasons for assessing themselves this way: "While I think I learned some of the ideals in PBI of what it should look like, I didn't learn practically how to think those through until I actually taught it," "the students weren't really given any lessons by me," and "it's very difficult to implement that [pure PBI] with the resources that I had and the timeframe that I had."

Some of those who did report that their implementation was authentic focused on only one aspect of PBI or a superficial characterization, such as the presence of a unifying theme. For example, when asked whether she had implemented PBI authentically as she understood it, one

**Table 4** Descriptions of projects implemented by ATS

| AT | Driving question or task | Learner product | Investigation | Science/math addressed | Collab. | Length |
|---|---|---|---|---|---|---|
| 1 | 1. What would the decoration on a coke can look like flattened out?<br>2. How can we measure the height of a cell phone tower with a clinometer? | 1. 2D net of Coke can decoration<br>2. Measurement of height | 1. Students investigated what the 2D net of an image would be<br>2. Students made clinometers from instructions and discovered ways to use them to measure height of a cell phone tower | 1. 2D nets of 3D objects<br>2. Properties of right triangles | Yes | 1 day (each) |
| 2 | What makes bridges fall down? | Model of bridge, scale drawings, description of design | Students designed and tested bridges with the goal of greatest weight to payload ratio | Properties of triangles, triangle formulas | Yes | 2–3 weeks |
| 3 | What makes bridges break? | Model of bridge, scale drawings, description of design | Students designed and tested bridges with the goal of greatest weight to payload ratio | Properties of triangles, triangle formulas | Yes | 2–3 weeks |
| 4 | Create a map of the Earth indicating important geologic features and use it to predict future geologic trends | Map and presentation | Students were assigned roles in investigating properties of Earth regions, creating an annotated map, and making predictions | Properties of plate boundaries; causes of volcanoes, earthquakes | Yes | 2 weeks |
| 5 | Student-generated driving questions involving DNA technology (e.g., cloning) | Written report and presentation | Students researched and reported on genetic issues of their own choosing | Genetics, DNA | Yes | 3 weeks |
| 6 | Are my friends making me sick? | Report | Students read case studies, performed laboratory investigations, made report | Microbes, pathogens | Group labs, individual product | 1 week |
| 7 | How do robots work? What makes them move? | Robot | Students built a robot and documented its programming; competed against other robots in completing assigned task | Control algorithms, programming language | Yes | 3 weeks |
| 8 | Create a series of drawings of 2 and 3D objects, scale them and calculate properties; use what you have learned to create an original image | Booklet | Students created a booklet with prescribed exercises and an open ended summative activity creating an image | Properties of 2 and 3D figures (surface area, volume), scale factors (proportions) | No | 2 weeks |
| 9 | Come up with a system of inequalities to meet the following constraints; model data using linear inequalities | System of inequalities; predictions and answers to questions | Students complete a series of challenges involving linear inequalities and data | Linear inequalities | Yes | 3 days |
| 10 | Create your own tessellation tile that would cover the floor with no gaps (and the instructions for making it) | Tessellation tile and instructions | Students created their own tiles and described how they used them to fill a plane, incorporating translation, rotation, reflection | Translation, rotation, reflection, plane filling (graphing) | Yes | 1 week |
| 11 | Make a travel brochure for the planet of your choice | Brochure | Students researched characteristics of planets and created brochure | Properties of planets | Yes | 4 days |
| 12 | Construct your own parabola/ellipse and mechanically discover its focus, vertex, and directrix | Parabola or ellipse, | Students constructed geometric figures and measured their properties | Properties of parabolas and ellipses | | 2 days |
| 13 | How do we figure out quality of our water? | Report | Students engaged in lab tests of kinds, researched water issues. | Water quality, ion concentration, acid–base chemistry | Group labs, individual product | 8 days |
| 14 | See how natural selection (predation, reproduction) works through a simulation (game) | None | Students engaged in a simulation of natural selection with assigned parts | Natural selection | Whole class | 1 day |

**Table 4** continued

| AT | Driving question or task | Learner product | Investigation | Science/math addressed | Collab. | Length |
|---|---|---|---|---|---|---|
| 15 | Are natural disasters getting worse? | Report | Students looked up natural disasters in media and reported | Earth science, natural disasters | Whole class | 1–2 days |
| 16 | Build a self-contained ecosystem that will allow the most organisms to survive in it | Terrarium | Students built self-contained ecosystems in 2 l soda bottles, populated them with organisms and observed | Interdependence of ecosystem; food chain | Yes | 2 weeks |

preservice teacher responded, "Yeah. We tried to do it, because it was the theme of, 'Are your friends making you sick?' So we examined different aspects of bacteria, how they make people sick, how they make people well. So I think so."

How did preservice teachers' perceptions of the efficacy of PBI relate to whether and how they implemented PBI? It was our expectation that students with higher affinity scores would be more likely to enact PBI and would create more authentic implementations, but this was not borne out in the data. Figure 1 is a plot of implementation score versus affinity score. Only four ATs' responses placed them in the lowest affinity category (scores of 0–4) at any time in the study, and none of these were in the subgroup who were interviewed and assigned an implementation score. However, the average affinity score of those who were interviewed was not significantly different than that of the entire group. The interviewees' average affinity score was 7.1 with a standard deviation of 1.7, and the average for our entire sample was 7.4 with a standard deviation of 1.5.

Since so few students (and none of those interviewed) scored in the lowest category, the graph in Fig. 1 includes only the medium (to the left of the dividing grid line) and high (right of the dividing grid line) affinity scores. Implementation scores are divided into minimal, moderate, and full, by the three horizontal grid lines. For the entire group, there was no apparent relationship between affinity score and implementation score. A strongly expressed belief in the efficacy of PBI did not necessarily translate into an authentic implementation of PBI. When examining the data for the individual cohorts, however, trends emerged.

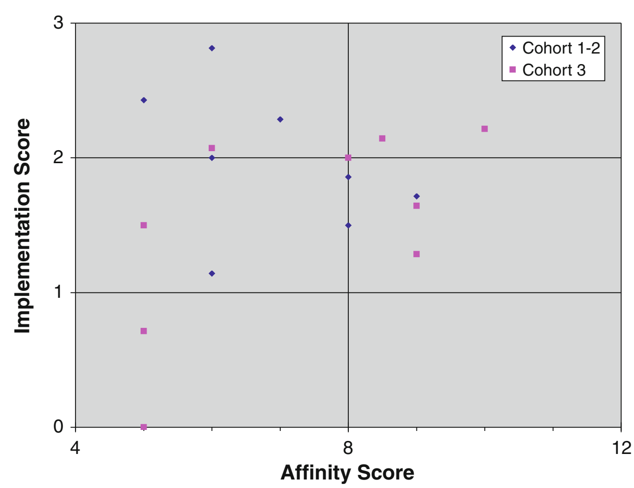


**Fig. 1** Implementation score versus affinity score for preservice teachers (ATs) who were interviewed

In Fig. 1, the diamond markers indicate data from the first two cohorts combined, both from the first year of the study. Recall that students in these two cohorts were strongly encouraged to implement the units that they or other students had developed in the PBI class. In these two cohorts, the ATs in the medium affinity category came closest to satisfying the criteria for PBI defined by experts (upper left sector). Although the small numbers and spread in the data do not justify an exact fit, a downward trend appears; ATs in these cohorts with higher affinity scores were not more likely to enact authentic implementations, according to these data.

In contrast, teachers in the third cohort (indicated by squares in Fig. 1) who scored in the highest implementation bin were all from the high-affinity category (upper right sector of the graph). Although, again, the small numbers and large spread in the data do not merit an exact fit, there does seem to be a trend toward more authentic implementation with higher affinity. All the ATs with less than minimal implementation scores were from this cohort, and they all had the lowest affinity score. Recall that a univariate analysis found no significant difference between the cohorts on the affinity scores themselves. This pattern of the contrasting trends between the two groups, and the general pattern of data distribution, held true for each element of the implementation rubric separately as well, indicating the average scores are reflective of the authenticity of the implementation of each element separately.

Of course, these data represent a select subgroup who volunteered to be interviewed, and they may show a selection bias. As mentioned above, none of the four ATs whose affinity scores were 4 or less on either the pre- or postsurvey volunteered to be interviewed. However, the fact that the average affinity score for the subgroup who were interviewed was not significantly different from the average for the entire sample we studied speaks against a large sample bias.

## Discussion

The preservice teachers surveyed tended to focus on the more general characteristics of PBI as a student-centered approach (hands-on, discovery learning, group work) and on its more superficial aspects (length or existence of an activity labeled as a "project"), as opposed to the unique characteristics identified by experts (e.g., driving question; tangible outcome or product; authentic, student-driven task) or the elements necessary for "doing with understanding" (cognitive tools, continuous assessment, and other scaffolds; Barron et al. 1998, p. 272). This finding is perhaps not surprising given that novices of all sorts tend to focus on more superficial aspects of tasks (Chi et al. 1981). Further, although these preservice teachers had opportunities to study, observe, and design project-based curriculum units in previous coursework, until their apprentice teaching semester they had only limited opportunities to actually implement PBI. Repeating the words of one preservice teacher after implementing a PBI unit, "While I think I learned some of the ideals in PBI [previous course] of what it should look like, I didn't learn practically how to think those through until I actually taught it."

On the other hand, the apprentice teaching semester itself did not seem to change these characterizations significantly. Given that the majority of ATs either did not implement PBI at all, or did not implement it in authentic way, this is not surprising. Only the emphasis on length in the descriptions of PBI seemed to change as a result of the apprentice teaching experience. We conjecture that as students began to rationalize their understanding of PBI with what they were able to accomplish and witness in classrooms, they lost the emphasis on length. In particular, the regimen of curriculum requirements forced students to limit themselves to the time periods given in prescribed curriculum guides. If the unit was associated with triangles, it needed to fit within the assigned period of study for triangles, regardless of how much time their students might need to respond to a driving question or task. In the words of one preservice teacher after apprentice teaching,

> Time, I think, is the biggest issue. You just felt like you had to move on and you had to be a certain place at a certain time in the [prescribed curriculum]. I don't think there's any way I could have fit that [the unit he had originally planned] in.

Another stated, "But, you know, being the student teacher, I just had to go by the guidelines that they had set, and we had this certain amount of time. Nobody else was doing it this way."

Indeed, time was one of the mostly commonly cited barriers to implementation on both the pre- and postsurveys. In general, the barriers to implementing PBI cited on the survey prior to apprentice teaching were the same ones identified at the end of the apprentice teaching semester. These appear to have been realistic perceptions, as the same barriers, particularly time and a prescribed curriculum, were often described in depth in the interviews. The drop off in respondents citing that "PBI won't work" as a barrier to implementation may indicate that increased experience with the actual curriculum implemented in schools led to a recognition that the fact the something does not work does not prevent it from being implemented; further, the fact that it does work does not necessarily make it easier, or even possible, to implement. All we can say is that by the end of the semester, these ATs no longer gave a lack of belief in the efficacy of PBI as a reason why they did not implement it.

In fact, the ATs who had more restrained views of the efficacy of PBI but still enacted full implementations (upper left sector of graph in Fig. 1) felt that the experience benefited their students. They did not report the precollege students' behavior or preparation as a barrier in their interviews. One AT stated, "I would suggest [to future ATs] to at least try it, because it's a good experience. It's certainly different than just doing it lesson by lesson." Similarly, another said, "I think if you want them [teachers] to do a project, I think it's a good experience, because some of us who start our first year of teaching are going to go in there and be a little intimidated." Another AT stated,

> I think in terms of [the high school students], I think it was [successful] in some ways. It gives them hands-on experience. It gives them… I don't know. Doing something that appeals to creative people. Like, one of the kids in my class that I would have never thought would get excited about anything got really excited about it and [was one of the most successful].

One participant noted, "I think it taught my students to be really self-reliant and to depend on their group members." Another cited classroom management:

> I think that without even instructing [the classroom students] or telling them what to do, they, they were self-motivated, and I think that having projects like this really gets kids to actively think, and you're not trying to force them to do anything, but they ask questions on their own, and they're looking for alternative ways to modify their creation, and they're looking around to see how other kids did their projects, so I think classroom management is pretty good.

Another AT believed that the PBI was "a good foundation" for later coursework, adding "I think it's always more useful when you have somthing that's practical and not something that's abstract."

Some of ATs with moderate- to full-implementation scores continued to express concerns about the barriers to implementation:

> I think that you have to take in for account that some students are going into the schools that have a set curriculum, like that's just unavoidable. It happens. I got lucky that my school had this. They have a couple each semester, and I just happened to be in one of the 6 weeks where it happened. But some schools don't have that.

Even these teachers, however, were adamant that they would implement their PBI units again, albeit possibly with refinements.

Surprisingly, students with higher affinity scores (those on the right half of the graph in Fig. 1) were not always more likely to carry out authentic implementations of PBI. One might speculate that the students who were more realistic about PBI, those who saw some value in the approach but also were cognizant of the barriers to implementation and the tradeoffs likely to be encountered in implementing the approach, were best prepared to enact PBI in the classroom. The lack of a trend toward more authentic implementation scores corresponding to higher affinity scores clearly is strongly influenced by those ATs from the first two cohorts who adopted PBI, albeit reluctantly, in response to programmatic encouragement. The pro-PBI stance of the preparation program in the Apprentice Teaching course during that time might have raised the implementation scores of those with low affinity, leveling off the affinity versus implementation trend or even reversing it.

It is also possible that the students who fell in the high-affinity category had a simplistic understanding of the method, that it only involved something which might be called a project, or that any sort of discovery, student-centered learning would constitute PBI. Thus, basing their unqualified endorsement on that categorization, the students did not include all the essential elements recognized by experts in their implementation. This conclusion is supported by the large number of ATs who simply described PBI as being inquiry, discovery learning, or group work.

Some preservice teachers with high affinity for PBI in Cohort 3, which received no added support toward implementing PBI as part of apprentice teaching, might have experienced (or perceived) barriers to authentic implementation that they were unable or unwilling to surmount. One AT explained her reasons for not implementing more authentic PBI:

> We moved so fast. It's actually kind of…I had never been in a class where we moved so fast. They take a test once a week in the class. And I was in honors classes in high school and I don't remember moving that fast….it was just a lot of planning for a class that was already moving so fast… And I would have wanted to do a long-term project, and I did think about it. I would have wanted to do it, but I just…–they complained every day (jokingly complained) about the amount of homework and stuff. Because pre-AP [Advanced Placement] kids, they have a lot of homework in all their other classes, too. But I could definitely (do PBI) in the future when I felt more prepared to implement stuff like that, I could definitely do it. And I think it would be something worthwhile to do. So, that was my reasons, we tested

> every week and gave them mounds of homework. So, as a first-semester teacher, that's pretty daunting to see and deal with.

For this AT, scheduling and prescribed curriculum constraints were insurmountable. For others, the need to align with what their mentor teacher was doing inhibited implementation:

> I would have liked to use it, and it would have been really nice, but as a student teacher, what you're doing, what you do is based on what your cooperating teacher does, and …there's also that element of, "We've got to get through all this other information and get ready for the TAKS [high-stakes, standardized Texas Assessment of Knowledge and Skills] test."

## Conclusions and Implications

We see implications for preservice teacher programs arising from each of our findings. First, practical design features, like the design principles espoused by Barron et al. (1998), need to be made explicit in teacher preparation coursework. The preservice teachers we studied were much more conversant with inquiry-oriented and collaborative instruction than with the design elements that experts view as essential to making PBI work. Our teachers were generally comfortable with small scale, highly structured, inquiry-oriented activities, possibly tied together by a theme, as evidenced in many of the projects in Table 4. However, they needed encouragement, time, and experience to see how these smaller activities might be incorporated, possibly as benchmark lessons, into full projects driven by open-ended, authentic questions or tasks, becoming more student directed while still meeting the same learning goals.

As noted above, one AT summarized this well by saying, "While I think I learned some of the ideals in PBI of what it should look like, I didn't learn practically how to think those through until I actually taught it." Another said,

> I think it was worth doing…for me especially. [I was] learning some practical things about how to teach projects and how to make them or how to think them through really well beforehand to where everything that you're teaching them is needed and relevant towards the end goal of a project. So it was helpful for me.

Second, novice teachers need opportunities and encouragement to implement PBI in their classrooms. In response to the expectation that they would implement a PBI unit, some of the ATs in our first two cohorts did so very successfully, even though they were cool to the idea initially. Our results show that an emphasis on implementing PBI as part of apprentice teaching can pay off in terms of more reluctant certification candidates actually implementing PBI, even authentically. None of the ATs who actually implemented PBI in our study described the experience as negative. Our results corroborate those of Clayton (2007), who found that for some 1st- and 2nd-year teachers, changes in thinking about reform curriculum must be preceded by actually implementing the curriculum: Learning comes with doing. Clayton also noted that the positive pressure to enact curriculum projects provided by cohort-based professional development "was the support that was necessary to inspire risk taking in an accountability environment" (p. 227).

Apprentice teachers also cited the benefits of practical experience with PBI:

> So I think I understand PBI better now after the class and after having to teach it, than I did necessarily learning it in the class. Because while I think I learned some of the ideals in PBI of what it should look like, I didn't learn practically how to think those through until I actually taught it. And then it gives you that experience to reflect on and say, "Now I can do it."

Another said,

> I'm going to know now a little bit about what the pitfalls might be or what I need to say ahead of time or maybe how much time I need to spend doing what. I really think that it's been helpful to have this kind of first dry run, if you will.

These findings run counter to stage models of teacher development that assert that "the beginning science teacher is just concerned with surviving and can only consider the most pressing issues related to teaching" (Luft et al. 2007, p. 25). Lowering expectations about what kinds of curriculum novice teachers can implement may deny them important opportunities for growth; such opportunities are most likely to come to fruition when accompanied by the support of a professional development program. As one AT said,

> If you've tried a project, good or bad, you tried a project, you know how it went, you know what you'd probably change or what you'd keep or what you would adapt for other projects, it gives you a little bit of insight for the future, a little bit of hope.

Finally, an unsupportive school environment can serve as a major impediment to novice teachers' intentions and desires to implement PBI, despite encouragement and support from professional development programs. This is particularly true for teachers in training who are still operating under the auspices of a classroom mentor teacher, but also for other novices (Clayton 2007) and, in fact, all teachers. In the words of one AT we interviewed,

> I think that [to require ATs to implement PBI] would have been great—in Candy Land. [laughs] I think there's got to be a lot more work between [the certification program] or whoever is doing this and the school district and the cooperating teachers. …When some of those problems are fixed, then you're going to have an environment where the teachers can implement what they do. But I could not imagine being a student teacher coming in without those resources and trying to scramble to implement something like that.

Therefore, care should be taken in situating apprentice teachers in the most supportive environments possible. In the end, those supporting the professional development of teachers must have high expectations for success, but also must provide the necessary scaffolding.

## Limitations and Further Work

It is important to note that the participants in this study were all certification candidates from a single teacher training program, one that emphasized PBI as part of its curriculum. That being the case, these results will not necessarily generalize to other programs. Similar research on how preservice teachers in other programs view PBI and how their conceptions relate to implementation in apprentice (student) teaching is also needed. As noted above, this work represents only a first step in responding to the Windschitl (2005) call for longitudinal evidence on the effectiveness of particular elements of teacher preparation programs. A study of program graduates' implementation of PBI as they move into their own classrooms is also needed to resolve the question of how these future teachers would act absent the supervision of a mentor teacher, but also further in time from the influence of program coursework. Such a study of program graduates has been implemented at a minimal level, and plans are underway for a more thorough investigation.

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## Appendix A

Survey instrument.

Project-Based Instruction (PBI) Survey

Name ____________________________________________

Sex: F M

Major: ________________________

1. What do you consider to be the key elements of Project-Based Instruction? In other words, how would you recognize PBI in a secondary math or science classroom?

2. Rank how much you agree with each of the following statements.

a. *In theory*, PBI represents best practices in secondary math and science instruction; all instruction should be done in this format.

Strongly agree Agree Disagree Strongly disagree

b. *In practice*, PBI represents best practices in secondary math and science instruction; all instruction should be done in this format.

Strongly agree Agree Disagree Strongly disagree

c. PBI represents one of a spectrum of valuable approaches to instruction. Good secondary math and science instruction should include both project-based and non-project-based instruction.

Strongly agree Agree Disagree Strongly disagree

d. PBI should serve as an overlay to traditional instruction, providing a connecting framework. It enhances traditional instruction but is not critical in secondary math and science classrooms.

Strongly agree Agree Disagree Strongly disagree

e. PBI is useful as a motivator to get students to learn material. PBI should serve as a reward in secondary math and science classrooms but is not a way to convey content to students.

Strongly agree Agree Disagree Strongly disagree

f. PBI is a distraction in secondary math and science classrooms. This format of instruction does not contribute to learning.

Strongly agree Agree Disagree Strongly disagree

3. Briefly describe how you plan to implement PBI this semester (if at all). Please include the source for any curriculum materials you will be using.

4. Which of the following best characterizes your feelings about how the [program] courses have prepared you to implement PBI?

a. I feel completely prepared for a full implementation of PBI.
b. I feel fairly well prepared to implement PBI at some level.
c. I don't feel that I am any better prepared to implement PBI that I was before I entered [program].
d. I feel less confident and enthusiastic about PBI after my [program] experiences to date than I did before.

Please explain your answer and list what experiences in [program] courses were particularly helpful in preparing you to or discouraging you from implementing PBI.

5. What do you see as possible barriers to implementing your plans for PBI?

## Appendix B

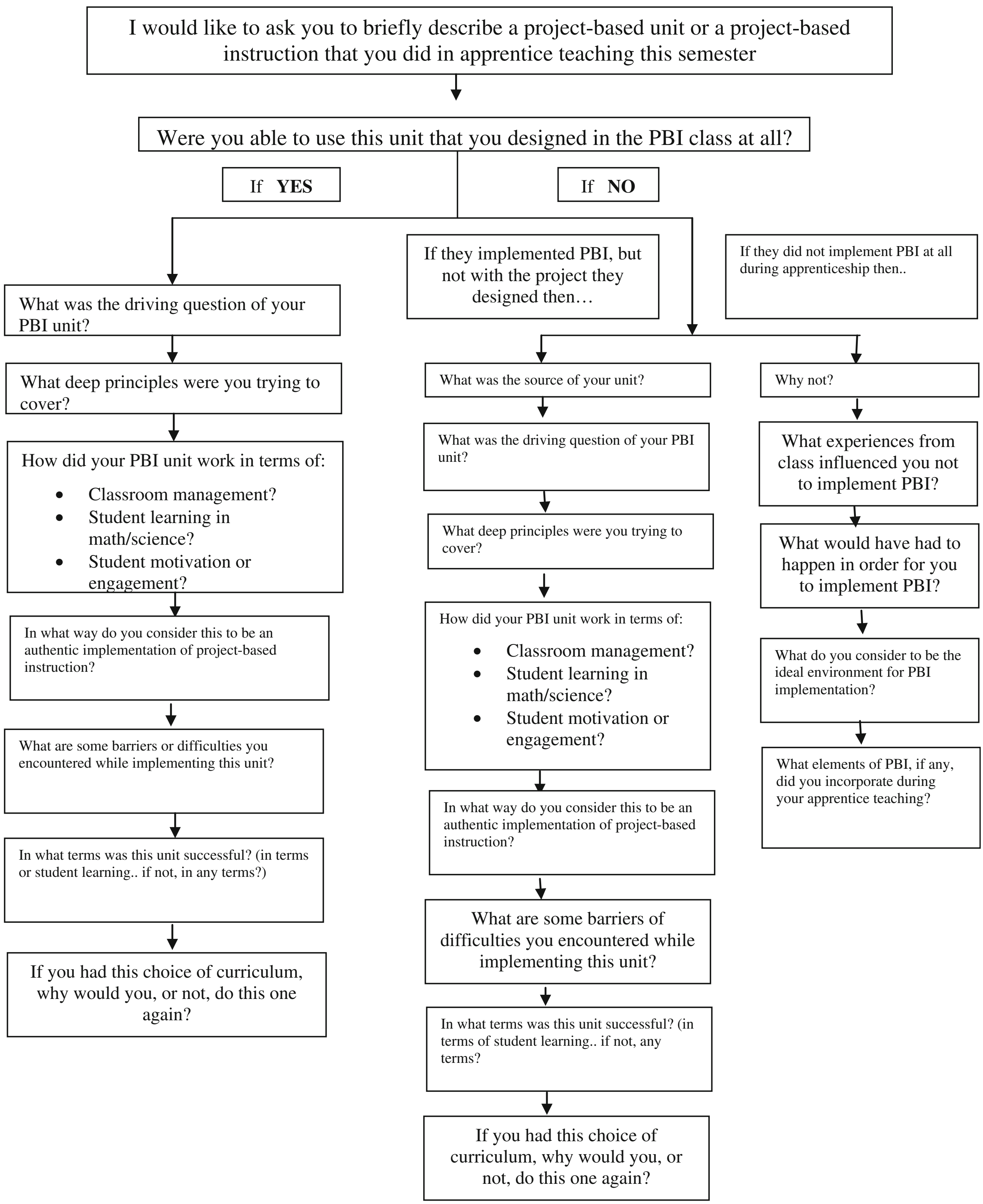
See Table 5.

**Table 5** Implementation rubric

| Component | Minimal implementation | Moderate implementation | Full implementation |
| --- | --- | --- | --- |
| Driving question | Question is supplied by instructor; predetermined answer | Students have some say in selecting or narrowing question. Requires multiple data sources. Answer not completely constrained | Question is meaningful to students, real-world problem with multiple, interdisciplinary data sources. Answer not previously known |
| Tangible product | Tangible product of some kind | Students use new concepts and apply information to create tangible product | Students new concepts and apply information to create tangible product; includes multiple ways of representing information |
| Investigation | Hands-on, minds-on activity | Student-driven, complex task | Authentic, student driven, complex. Students learn concepts, apply info, represent knowledge in multiple ways |
| Cognitive tools | Access to learning tools of some kind | Access to multiple tools | Cognitively oriented collaboration and visualization tools |
| Collaborative activity | Students report results to others | Task includes collaboration between students to generate product | Task requires collaboration between students and others to generate product |
| Assessment | Some form of formative assessment | Authentic formative and summative assessments | Authentic assessment requiring multiple forms of knowledge representation |
| Scaffolding | Some form of scaffolding | Instructor provides scheduling milestones, inquiry is seeded with powerful ideas | Scheduling milestones, benchmark lessons, social structures to facilitate collaborative learning |

## Appendix C

Interview protocol.



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