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A Retrospective Examination of STEM Teachers' Use of Project-based Learning Once Employed

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ABSTRACT

This study explored science and mathematics teachers' knowledge and beliefs about project-based instruction (PBL). Data included two focus groups, and a 12-item questionnaire administered to 138 teachers. The response rate was 70% (n=96). Results show strong teacher knowledge of PBL Gold Standard Design Elements/Teaching Practices, but low usage by teachers (68%) as less than 26% of instructional time was used to implement PBL. Of the respondents, 33 indicated they used PBL as a teaching strategy. Teachers felt prepared to use PBL, suggested it made learning fun, and helped students acquire academic content and 21st century skills. Challenges included: funding support, accountability requirements, time constraints, and lack of professional development support.

Keywords: project-based learning, PBL, secondary science education, secondary mathematics education

Introduction

Educator preparation programs should advance and strengthen the teacher pipeline in ways that support PK-12 learning. As part of this effort, programs rely on evidence to evaluate and continuously seek to improve. Although Texas produces the largest number of mathematics and science teachers in the United States (Marder, 2020), teacher shortages in this area persist with almost four out of 10 teachers having not more than five years of experience (Landa, 2024). For this reason, this program focused on the preparation of mathematics and science teachers in an effort to develop quality teachers who will remain in the classroom. This program began as part of a national effort spearheaded by the UTeach Program to replicate a proven approach to prepare STEM teachers. One part of the teacher preparation curriculum includes problem-based learning (PBL) to help students acquire knowledge and skills that are useful in life by investigating relevant, real-world problems. As faculty are concerned with continuous program improvement and providing teachers with a research-based teaching practices, we wanted to know to what extent teachers used PBL once they became a classroom teacher. Specifically, this study investigated the knowledge and beliefs of newly certified science and mathematics classroom teachers who received teacher training and early field experiences in PBL as part of their pre-service training. This study addresses a gap in the literature as it seeks to examine if mathematics and science teachers actually implement the teaching model of PBL once they become a classroom teacher.

This study used the Buck Institute for Education (n.d.) formal definition for PBL, *a teaching method in which students gain knowledge and skills by working for an extended period of time to investigate and respond to an authentic, engaging, and complex question, problem, or challenge*. As such, PBL is a method that takes advantage of students' inherent drive to learn as they engage in a deep exploration that is designed to construct essential knowledge. The students' investigation uses both tools and skills to generate products that result from sustained inquiry, accompanied by recursive feedback and performance-based assessment. It should not be overlooked that design criteria for PBL must include the development of *new* skills and the construction of *new* knowledge, and it is the project requirement infrastructure that supports and structures the development of these new skills and knowledge.

The following research question was used to examine how teachers use PBL design and practices once they become certified teachers and are employed as a teacher of record:

> After participation in 70 hours of PBL instruction as a pre-service teacher, which of the Gold Standard PBL project design elements and PBL practices do in-service teachers report using as part of PBL design and implementation?

Framework for the Study

The Gold Standard PBL Model is the framework used for this study. The framework includes both essential design elements for developing high-quality projects together with teaching practices to help teachers and others to assess and continuously improve their practices. All design elements *and* project-based teaching practices focus on the development of key knowledge commonly associated with discipline standards, understanding, and success skills (i.e., critical thinking, collaboration, communication, and creativity). These elements set the stage for learning and should be emphasized throughout the project. The seven essential project-design elements (Buck Institute for Education, n.d.; PBL Works, 2022) include: (1) a challenging problem or question; (2) sustained inquiry; (3) authenticity; (4) student voice and choice; (5) reflection; (6) critique and revision; and (7) public product. In addition to the PBL design elements, this study examined project-based teaching practices for Gold Standard PBL (Boss & Larmer, 2018; PBL Works, 2022). These practices include: (1) Building the Culture; (2) Designing and Planning; (3) Aligning to Standards; (4) Managing Activities; (5) Assessing Student Learning; (6) Scaffolding Student Learning; and (7) Engaging and Coaching.

Literature Review

Origins of PBL

The project method can be traced back to 1577 to master builders in Rome who sought to advance their standing through the development of a profession through science and education. More than 150 years later, design problems (projects) were given to advanced students of the Academie Royale D'Architecture in Paris to demonstrate that they could apply what they had learned into practice in the design of structures such as bridges, fountains, and churches (Phillips, 2014). From these early projects, three models developed. The linear model first taught skills then applied them to projects (Woodward, 1887). The holistic model moved the project from the end of the unit by placing students together to plan, learn skills, and ultimately construct a project. Instruction in the holistic model was an integral part of project construction that accompanied, but did not precede, the project (Richards, 1906). Finally, the universal model put forth by William Kilpatrick (1918) was strongly child-centered and generic in nature. There was no prescribed curriculum, and ideally the project was proposed and carried out by the students themselves. Kilpatrick (1918) included student motivation as an essential component of the project method, and created a typology of projects that did not link to specific subjects, nor did it require any active doing in terms of physical activity. It is interesting to note that Kilpatrick's (1918) concept was never successfully implemented, although his article, *The Project Method,* remains a classic text.

Even though Kilpatrick is often called the Father of the Project Method, he was fiercely criticized by prominent educators, philosophers, and social reformers of his time including Dewey, Thorndike, Horn, Charters, and Bode who outlined serious weaknesses in the Project Method (Phillips, 2014). Those weaknesses included: the claim that only the interests of the child would lead to the best results in learning; a lack of teacher guidance for issues related to subject matter, classroom management and student performance; promulgation of freedom that gave rise to selfish and individualistic attitudes in place of democratic and social virtues; and masquerading as a method of teaching instead of a philosophy of education (Phillips, 2014).

PBL and Dewey

It is the work of Dewey at the Laboratory School at the University of Chicago that clearly positioned the teacher as the guide for learning and not the student themselves. Dewey (1934) stated,

> It is the business of the educator to study the tendencies of the young so as to be more consciously aware than are the children themselves what the latter need and want. Any other course transfers the responsibility of the teacher to those taught. (p. 85)

Dewey's philosophy included three components of Herbartian thought; the psychological, the sociological and the logical.

First, the natural impulses and interests of children was to be used by the teacher to draw them to the learning topic. Dewey identified four interests possessed by all children: communication, making and building, exploring and investigating, and artistic expression and self-realization. Thus, the main function of the teacher was to take the curriculum and transform it into problems that students could investigate in authentic ways, and on their own, with little direction from the teacher (Knoll, 2014). In Dewey's view, the student was not capable of planning projects and activities, so they needed a teacher to provide guidance and direction to ensure that learning would occur (Rohr & Lenhart, 1995). All teaching methods were rooted in scientific thinking and the method of the educative experience. The second component of Herbartian thought utilized by Dewey held that children were to gain sociological components that would enable them to take part in democracy. The factors of socialization, namely, common aims where interchange of thought is prevalent, a spirit of cooperation, and division of labor that binds students together were resulting sociological components. Lastly, as a result of the learning experience, the students would learn content and methods that would contribute to a progressive society. In addition to Dewey's philosophy, project-based instruction is also situated in constructivism, an activity-based learning where children explore and engage in learning as a process used to create meaning (Greeno, 2006; Oguz-Unver & Arabacioglu, 2014).

PBL Impact on Students

Currently, PBL has grown in popularity as an alternative to direct instruction (Ogus-Unver & Arabacioglu, 2014) with its focus on a student-centered setting (Kokotsaki et al., 2016) and with projects functioning as the core of the curriculum (Krajcik & Shin, 2014). It should be noted that PBL has often been used in the sciences (Krajcik & Shin, 2014; PBL Works, 2022; Rogers et al, 2011) and in mathematics (Chen & Yang 2019; Han et al., 2015; Holmes & Hwang 2016). Importantly, PBL has been shown to increase student motivation (Krajcik & Czerniak, 2018), as well as well as student interest in content (Barak & Asad, 2012; Bell, 2010; Holmes, 2011), engagement in learning (Almulla, 2020; Bender 2012; Tseng et al., 2013), increasing academic achievement (Chen & Yang, 2019) and metacognition (English & Kitsantas 2013; Thomas, 2008).

A meta-analysis by Chen and Yang (2019) explored academic achievement associated with PBL and found a large positive effect on academic achievement when compared to direct instruction. These authors also found the mean effect size was influenced by subject (social sciences was best), hours of instruction (at least two hours), and technology support (particularly with teacher knowledge of how to use technology to support learning (Eskrootchi & Oskrochi, 2010). The comparison of PBL to direct instruction also showed that group size did not affect achievement, nor did educational stage (i.e., primary, secondary, college).

Teaching and PBL

There are a few studies about the use of the PBL model experienced by secondary mathematics and science pre-service teachers once they become teachers of record (Burlbaw et al., 2013; Chen & Yang, 2019; Gijebels et al., 2005; Han et al., 2015; Hasni et al., 2016; Kanter, 2009; Krajcik & Shin, 2014; Walker et al., 2011). That is, studies that focus on whether preservice teachers enact in the classroom what they studied as a pre-service teacher while in the university or via significant professional development. As instruction for PBL is negotiated collaboratively between the teacher and the student(s), conceptualization of PBL by the teacher is critical for implementation (Fallik et al., 2008; Tsybulsky & Muchnik-Rozanov, 2019). Specifically, there is more to it than understanding the surface features associated with PBL (i.e., product, collaboration, autonomy). Rather, it is the core features (i.e., contextualized problem or question, product with a purpose, application of conceptual knowledge, inquiry) for which the teacher must show adequate knowledge and experience about in order to successfully negotiate learning and enable students to develop their own ideas and grow their own knowledge and skills (Grossman et al., 2018; Harrell et al., 2022; Kavanaugh & Rainey, 2017; Kavanagh et al., 2020; Kloser et al., 2019; Subramaniam et al., 2020).

Hasni and colleagues (2016) conducted a meta-analysis that included how teachers express the concepts and features of PBL. In that study, the main features used to define PBL included an authentic question or problems, engagements in design activities or investigations, collaboration, use of technology, and a final product (Krajcik & Shin, 2014; Parker et al., 2013). The teachers' justification for use of PBL included the learning of specific knowledge and skills that were situated in real world settings or practices; increases in student motivation; and the benefits of constructivist practices to enhance learning.

With these advantages in mind, it should not go unsaid that PBL can be a difficult practice to master. Challenges described by the teachers included managing the features of the model, such as formulating a problem or question (Krajcik & Shin, 2014), using inquiry (Veletsianos et al., 2016), access to resources, supporting claims (PBL Works, 2022), time constraints (Dole et al., 2016), and balancing monologic interactions with student discussions (Fallik et al., 2008; Larmer et al., 2015).

There are also a limited number of studies that show gains in teacher knowledge and confidence after engaging in professional development around PBL. For example, Gijebels and colleagues (2005) studied the impact of a PBL professional development on calorimetry and body systems in biology and showed higher levels of both content knowledge and pedagogical content knowledge for teachers' intervention (Gijbels et al., 2005). Walker and colleagues (2011) also found PBL was associated with large increases in teacher content knowledge and confidence along with technology integration.

Using an experimental design, Hixson and colleagues at the West Virginia Department of Education (2012) conducted a large study that compared the performance of teachers trained by the Buck Institute for Education in PBL to those who did not receive training. These authors found that trained teachers implemented 21st century skills more frequently and more extensively, regardless of content area, students served, or the presence of block scheduling. Similarly, Häkkinen and his associates (2017) demonstrated that PBL developed 21st century skills by promoting critical thinking, problem-solving, communication, teamwork, and creativity.

With regard to instruction, balance of direct instruction with inquiry allows students the opportunity to gain deeper understanding of content and processes (Arantes do Amaral et al., 2015; Grant, 2011; Grant & Branch, 2005; Markham, 2012; Özel, 2013; Veletsianos et al., 2016) while assessment practices trace and document mastery of knowledge and practices (Grant & Branch, 2005). Scaffolding, another important aspect of instruction, drives and supports student learning, allowing for opportunities to understand and take advantage of learning in ways that identify and bridge prior knowledge while addressing learning gaps (Arantes do Amaral et al., 2015; Gresalfi et al., 2012; Hmelo-Silver et al., 2007). Finally, it has been shown that the PBL approach provides the opportunity for inexperienced teachers to engage in transformative learning experiences, while supporting both professional and personal development (Tsybulsky & Muchnik-Rozanov, 2019).

Methodology

The purpose of the study was to examine teachers' use of PBL design and practices once employed as a certified teacher (i.e., teacher of record). Given this statement of purpose, the study used focus groups and data from a questionnaire to explore how employed teachers who graduated from a science and mathematics teacher program used, or did not use the PBL teaching method. For those who were using it, this study explored the teachers' use of project design elements and project-based teaching practices. Institutional Review Board approval was granted for this study (No. 17-322) and SPSS Version 25.0 was used to analyze the data. The following research question was used to guide the study.

> After participation in 70 hours of PBL Instruction as a pre-service teacher, which of the Gold Standard PBL project design elements and project-based teaching practices do in-service teachers report using as part of PBL design and implementation?

In an effort to obtain rich data from a select constituency, a traditional purposive sampling technique was used in this study. According to Teddlie and Tashakkori (2009), "purposive sampling techniques involve selecting certain units or cases based on a specific purpose rather than randomly selecting" (p.173). Data collected and reported in this this study also follows the American Psychological Association's (2019) publication *Race and Ethnicity Guidelines in Psychology: Promoting Responsiveness and Equity*.

Participants

Participants in this study attended an R1 University that was Council for the Accreditation of Educator Programs (CAEP) accredited. Both science and mathematics programs were nationally recognized by CAEP, meaning students were provided a program of quality experiences that had undergone a rigorous external peer-review process by the academic community and other stakeholders. This program is one of 11 original UTeach replication projects that received five years of financial support and extensive feedback from UTeach. The purpose of UTeach is to establish innovative secondary math and science teacher preparation programs that successfully recruit, train, and retain excellent teachers to work in diverse high-need school settings (UTeach, 2024). The PBL course is part of this replication.

The ethnicity of the participants was determined using university records where ethnicity is self-reported: 10% Asian, 9% Black, 21% Hispanic, 52% White, and 9% did not report their ethnicity. Science and Mathematics teachers were almost equally represented as 45 (49.45%) were Mathematics teachers and 41 (45.05%) were Science teachers. The five remaining teachers (5.49%) were multidisciplinary teachers. Percentages do not equal 100% due to rounding.

All participants received a degree in their content area, such as a BA in Mathematics, BA in Biology, or BA in Chemistry, along with a minor in education that included teacher certification. Participant grade point averages were a minimum of 2.8 on a 4-point scale, a condition of CAEP accreditation. As part of the education coursework, students completed a 45-hour course in PBL, *Project-based Instruction in Math, Science and Computer Science* that included significant field experiences in a PBL school. It is this undergraduate pre-service teacher experience and whether or not it was enacted in the classroom as an in-service teacher (teacher of record) that is the focus of this investigation.

Data Sources and Instrumentation

Focus Groups

Data produced from focus groups is generally rich data in that it provides the opportunity to uncover complexities through rich descriptions (Hesse-Biber & Leavy, 2011). According to Hesse-Biber and Leavy (2011), "focus groups have a distinct advantage over other available research methods when the researcher doesn't know all of the issues surrounding a topic" (p.163). A focus group for science teachers and a separate focus group for mathematics teachers was used to identify themes about knowledge and implementation of PBL. The Science focus group included six female, first-year teachers, and the Math focus group included five first-year teachers (one male and four female). All were program graduates and reported implementing a PBL unit in their classroom.

For each of the two focus groups, structured interviews were used by the authors who adhered to the transcription process as described by Mergenthaler and Stinson (1992). Participants were selected because of their rigorous preparation as an undergraduate, and their content expertise in science or mathematics. The data were transcribed using a transcription service approved by the university review board.

Three of the five authors initially reviewed and manually coded the transcripts thematically. Differences in coding were resolved through a process of consensus (Braun & Clarke, 2006), that is the three authors consulted each other about how they applied codes to the focus group transcripts and sought to correspond themes to participants' constructions of implementing PBL in their classrooms as expressed in their focus group interview transcripts. Intercoder agreement (Kurasaki, 2000) was used as a trustworthiness technique in this study. In seeking agreement on a consensus on preliminary themes, an 80% coherence was sought between each author's applied codes and preliminary themes.

Questionnaire

Based on these identified themes from the focus groups, together with selected questions from the National Survey of PBL and High School Reform (Ravitz, 2008), a questionnaire was developed. The questionnaire used duplicate questions from the National Survey of PBL and High School Reform

(Ravitz, 2008), combined with questions utilizing the focus group themes. Twelve questions with varied Likert scale ratings tailored to the question were created to describe teacher knowledge of PBL design and teaching practices The face validity was established via three experts who evaluated the questions' effectiveness regarding capturing the topic under investigation. As a result, the questions were refined, and the response scale was changed to include verbal labels. This was done in an effort to reduce ambiguity in the translation of subjective responses and to clarify the meanings of the scale points. Next, the questionnaire was piloted with mathematics and science teachers and their feedback was used to further improve the context and clarity of the questions. Due to the nature of the purposive sampling, which was predetermined and included only math or science teachers, the sample population was small and did not allow for further examination of the underlying components. The data collected from the questionnaire was used to provide a generalizable view of teachers' beliefs regarding PBL and utilization of PBL practices in their classroom while the teacher of record.

Reliability analysis was not conducted for this study due to the small sample size. Kline (1986) cautions against performing analysis for samples fewer than 300. Although there is some support for reliability analysis for smaller sample sizes (Nunnally, 1994; Yurdugul, 2008), Samuels (2017) cautions that attempting analyses on samples fewer than 30 is not feasible. The questionnaire was electronically mailed to 138 science and mathematics teachers who were graduates from a teacher education program for mathematics and science at a large university in North Texas. Follow up reminders were provided twice in an effort to improve the response rate of the questionnaire.

Results

Of the 138 teachers in the sample, 96 responded to the questionnaire and 91 participants completed the questionnaire. According to Nulty (2008) and Van Horn (2009) this is respectable response rate. Of the 96 teachers who responded to the questionnaire, 33 (34.38%) indicated that they used PBL as an approach to instruction based on the following criteria: engaged students in an extended investigation; required in depth inquiry into a topic; included student self-direction (voice and choice); and presented findings, results, or conclusions. Of the 33 respondents, 25 finished all questionnaire items. The 25 teachers who completed the questionnaire are the focus of this study.

Context

Of the 25 teachers who used PBL and completed the questionnaire, fourteen were mathematics teachers, ten taught science, and one taught in an interdisciplinary setting. All but one teacher taught in a secondary school setting and teachers were assigned to preparations that spanned different grade levels (grades 9 – 12). Almost all teachers taught in block or flexible school settings (87%) with a school-wide emphasis on problem-based, project-based, or inquiry learning (76%) and a school-wide emphasis on acquisition of 21^{st} century skills (100%). Seventeen teachers (68%) indicated they spent 25% or less instruction time using PBL. Three teachers (12%) indicated they spent approximately 50% of instructional time facilitating PBL, with an equal number spending 75% of their time, and two teachers (8%) used PBL exclusively for instruction. Outside of the 70 hours of training the teachers received as an undergraduate, little professional development was provided as a teacher in the classroom that would support the use of PBL. Eleven teachers (44%) received no professional development training, ten teachers received a half or one day of training (40%), and four teachers (16%) received 4 or more days of training that supported the use of PBL.

Beliefs about Students and Use of PBL

As shown in Table 1, all teachers expressed the belief that PBL is an effective teaching strategy for high-achieving and average-achieving students (Barak & Asad, 2012; Bell, 2010; Chen & Yang, 2019; Holmes, 2011).

Table 1

Teacher Beliefs about the Use of PBL for Various Student Populations

	Strongly Disagree	Tend to Disagree	Not Sure	Tend to Agree	Strongly Agree
High Achieving Students	0 (0%)	0 (0%)	0 (0%)	3 (12%)	22 (88%)
Average Achieving Students	0 (0%)	0 (0%)	0 (0%)	9 (36%)	16 (64%)
Low Achieving Students	3 (18%)	4 (25%)	1 (06%)	8 (50%)	0 (0%)
Students Who Lack Motivation	2 (8%)	2 (8%)	4 (16%)	10 (40%)	7 (28%)
Student with Limited English Skills	1 (4%)	2 (8%)	4 (16%)	9 (36%)	9 (36%)

Note. Not all teachers responded to this item.

Sixteen of twenty-five teachers responded to the question regarding low-achieving students and eight out of 16 teachers (50%) indicated its use with low-achieving students. Seventeen of twenty-five teachers (68%) indicated PBL was appropriate for students who lack motivation, with four teachers (16%) "not sure" and four teachers (16%) who disagreed to some extent about its usefulness with students who lack motivation. Similarly, 18 teachers (72%) agreed to some extent that PBL could be used with students who have limited English skills, while four teachers (16%) were "not sure" and three teachers disagreed to some extent.

Beliefs About Challenges that Limit the Use of PBL

Similar to other studies, 40% of teachers considered student proficiency/familiarity with PBL and the time needed to carry out a project as major challenges that limited the use of PBL (Dole et al., 2016; Fallik et al., 2008). As shown in Table 2, moderate challenges included too many students (44%), a lack of funding or resources (32%) finding time to create or plan projects (28%), lack of PBL examples in the subject area (24%), and testing and accountability requirements (24%).

Table 2

Teacher Challenges that Limit Use of PBL (n = 25)

	Not a Challenge	A minor Challenge	A moderate Challenge	A Major Challenge
Too many students	1 (4%)	10 (40%)	11 (44%)	3 (12)
Short class periods	10 (40%)	7 (28%)	4 (16%)	4 (16%)
Classroom space	8 (32%)	8 (32%)	5 (20%)	4 (16%)
Student proficiency with PBL	3 (12%)	7 (28%)	5 (20%)	10 (40%)
Attendance and/or student behavior	8 (32%)	11 (44%)	2 (8%)	4 (16%)
Parents expect direct instruction	15 (62%)	3 (12%)	5 (20%)	2 (8%)
Testing and accountability requirements	7 (28%)	8 (32%)	6 (24%)	4 (16%)
Lack of funding or resources	9 (36%)	7 (28%)	8 (32%)	1 (4%)
Lack of PBL examples in subject area	7 (28%)	10 (40%)	6 (24%)	2 (8%)
Time to find, create or plan projects	5 (20%)	8 (32%)	7 (28%)	5 (20%)
Time to carry out projects	5 (20%)	7 (28%)	3 (12%)	10 (40%)

Lack of PD or coaching	11 (44%)	6 (24%)	6 (24%)	2 (8%)

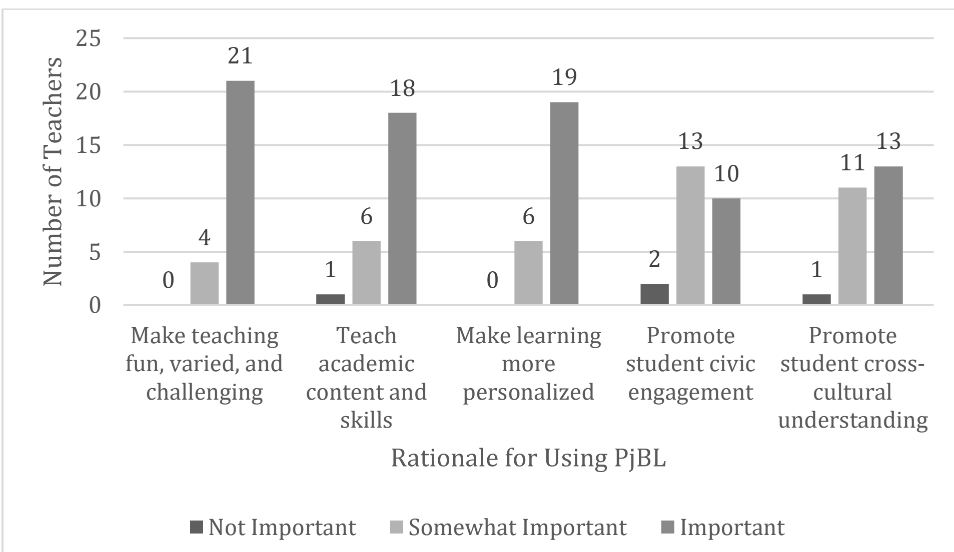
Minor challenges included attendance or student behavior (44%), too many students (40%), lack of PBL examples in the content area (40%), classroom space (32%), testing and accountability requirements (32%), finding time to create or plan projects (32%), and time to carry out projects (28%). Parent expectations for direct instruction (62%), lack of PD or coaching (44%), short class periods (40%), lack of funding or resources (36%), classroom space (32%), attendance and/or student behavior (32%), and lack of PBL examples in the subject area were most often identified as "not a challenge" (see Table 2).

Teacher Rational for Use of PBL

Figure 1 shows "important reasons" teachers selected for using PBL. Similar to other research (Bell, 2010; Hawkins, 2017) a strong majority of teachers' "most important" reasons included making teaching and learning more varied, challenging, or fun (21 *important* and four *somewhat important*); to teach academic content knowledge and skills more effectively (18 *important*, six *somewhat important*, and one *not important*); and to making learning more personalized and tailored to student individual interest or needs (19 important and six somewhat important).

Figure 1

Rational for Using PBL (n=25)



Other reasons for use of PBL included promoting student civic engagement (10 *important*, 13 *somewhat important*, and two *not important*) and promoting student cross-cultural understanding (13 *important,* 11 *somewhat important*, one *not important*. The questionnaire results suggest that teachers meet the Gold Standard PBL element of public view together with Gold Standard PBL teaching practices related to building culture, design and plan, and engage/coaching.

Use of Essential Project Design Elements and Project-based Teaching Practices for Gold Standard PBL

Table 3 shows Project Design Elements and Project-based Teaching Practices most often used by the teachers.

Table 3

Average Item Response by Element/Practice with Mean, Standard Deviations, Median and Modes (n = 25)

Practice	Element or Practice	Mean	SD	Median	Mode
Challenging problem or question [a]	1	4.36	0.82	5	5
Authenticity [a]	3	3.32	1.23	4	4
Reflection [a]	5	4.14	0.97	4	5
Public Product [a]	7	3.68	1.12	4	4
Design and Plan [b]	2	3.94	1.04	4	5
Align to Standards [b]	3	4.59	0.87	5	5
Assess Student Learning [b]	5	4.40	0.84	5	5
Scaffold and Student Learning [b]	6	3.14	1.00	3	3

Note. A 1-5 Likert Scale was used.
[a] Product Design Elements.
[b] Project-based Teaching Practices.

PBL Design Elements investigated included: a challenging problem or question, authenticity, reflection, and a public product. Challenging problems or questions along with reflections represent the project design elements used, to some extent, by the teachers. The mean for use of a *Challenging Problem or Question* was 4.36 and the median was 5 which suggests strong fidelity to this PBL element. A teacher commented about the purpose of driving questions in the PBL lesson. She said, "I think there's usually some kind of driving question. You could use the driving question to create a project and scaffold every day a little piece to the project." Challenging problems or questions are central to PBL (Krajcik & Shin, 2014; Larmer et al., 2015). These problems or questions are aligned to learning goals and are open-ended, allowing for more than one answer, in an effort to motivate the student. As this element is central to PBL, significant time was spent during preservice teacher training musing and reviewing first drafts initially by the university instructor and secondarily by an instructional coach.

The mean for *Reflection* was 4.14 and the median was 4 which again suggests the teachers used the element of reflection as an important part of the students experience with PBL. Reflection is integral to PBL as it deepens sensemaking and aids in the retention of learning and results in a higher-quality outcome. A teacher reflected about using PBL and stated:

> The hardest thing about PBL is that because the kids are discovering it on their own, they're not all gonna get it, you know? But it really does have to be a very intentional and its very time consuming, like, pre-loading type of thing that requires a lot, but I definitely think that it's worth the investment, even with testing.

As shown in Table 3, Gold Standards for project-based teaching elements were evident (Boss & Larmer, 2018; PBL Works, 2022). Three project-based teaching practices were frequently used: *Design and Plan, Align to Standards*, and *Assess Student Learning.*

The mean for *Design and Plan* was 3.94 and the median was 4 which suggests this teaching practice was an important component. Within the program, students are provided with extensive feedback involving critique and revision from the university instructor, content-area coach, and peers as they develop lessons that are aligned to standards and feature ongoing assessments. Each lesson must meet specified standards of quality before it is taught to students, and there is an emphasis on scaffolding to activate prior knowledge and connect to student interests (Arantes do Amaral et al., 2015; Gresalfi et al., 2012; Hmelo-Silver et al., 2007). The use of graphic organizers and the provision of examples, and learning progressions were used in the program to facilitate acquisition of content while attending to the needs of students (Grant & Branch 2005; Hmelo-Silver et al., 2007). In this questionnaire, every teacher indicated they used these practices to some degree in their classrooms. One teacher expressed, "I think that the teacher's job is to be very intentional in that, to make sure that they're guiding them. Every day it has to be a guided thing, and I think that people lose sight of what PBL is."

The mean for *Align to Standards* was 4.59 and the median was 5. Teachers are concerned with accountability. For this reason, aligning to standards provides the basis for the development of learning and is tied to evidence that learning is attained. One teacher described how important alignment to standards was in her school. She stated, "I will say that those testing pressures are very real, but I think that even just having one PBL project, is very worth it for the kids who experience taking something from beginning to end."

The mean for *Assess Student Learning* was 4.40 and the median was 5. As assessments provide evidence of what has been learned, they must be tied to standards and learning goals in ways that reinforce one another. The expectations for students must be clear to guide well-structured learning and monitor progress via use of assessment practices. An interesting example of formative assessment was described by a teacher while observing group work. She noticed some students were not contributing to the project, so she added a component for group members to evaluate one another. She stated, "So for them, I actually had them grade each other on that part for the equal amount of work and stuff, just to kind of see who they thought did the work and who they thought didn't, and they were very honest."

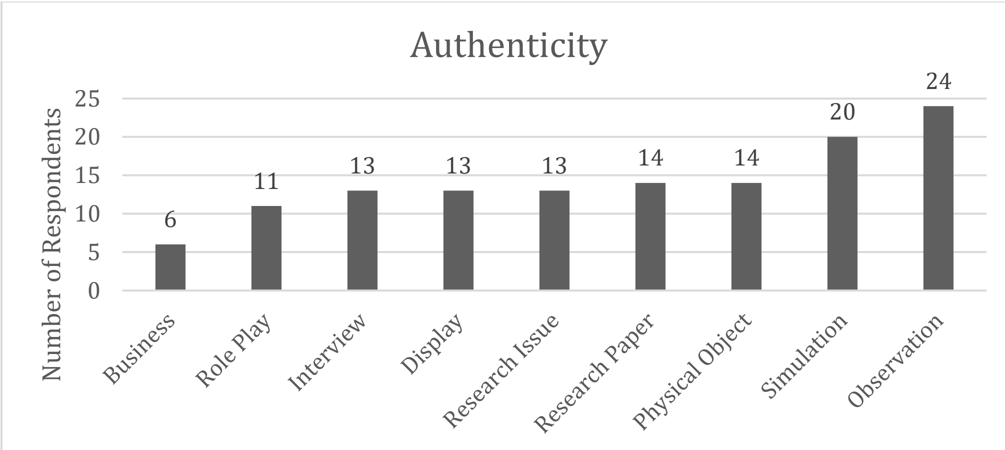
Authenticity

According to Parker and colleagues (2013), authenticity can be categorized as authentic to self (i.e., voice and choice, agency), or to others (i.e., public performance, products). Authenticity means engaging in projects that are real to the student or that impact the real world (Mann et al., 2020). That is, the project addresses a real need, the creation of a product, the setting up of a realistic simulation, or the use of scientific tools or processes. (Pepper, 2015).

For this study, simulation (80%) and observation (96%) were the types of experiences most often used to enact projects. See Figure 2 for this information.

Figure 2

PBL Gold Standard 3, Authenticity (n=25)



Approximately half of the teachers used the creation of a working prototype of a physical object/structure/device (56%), the presentation of research papers (56%) had students researching issues in the community (52%), display of artistic products/performances related to music, art, drama (52%), and interviewing family/community members to document experiences (52%). Role playing was also used to simulate solving of real-world problems (44%) as was simulation of running a business/service to the school or community (24%). One teacher described using PBL to teach different parts of the genetics lesson. She stated:

> One could be learning about fingerprinting and how everyone has their own fingerprint, and you know everyone has their own DNA, so you could teach them how to do fingerprinting. You could have someone who did fingerprinting for the police or something come in and teach them how to do it. You can bring in authentic audiences and stuff.

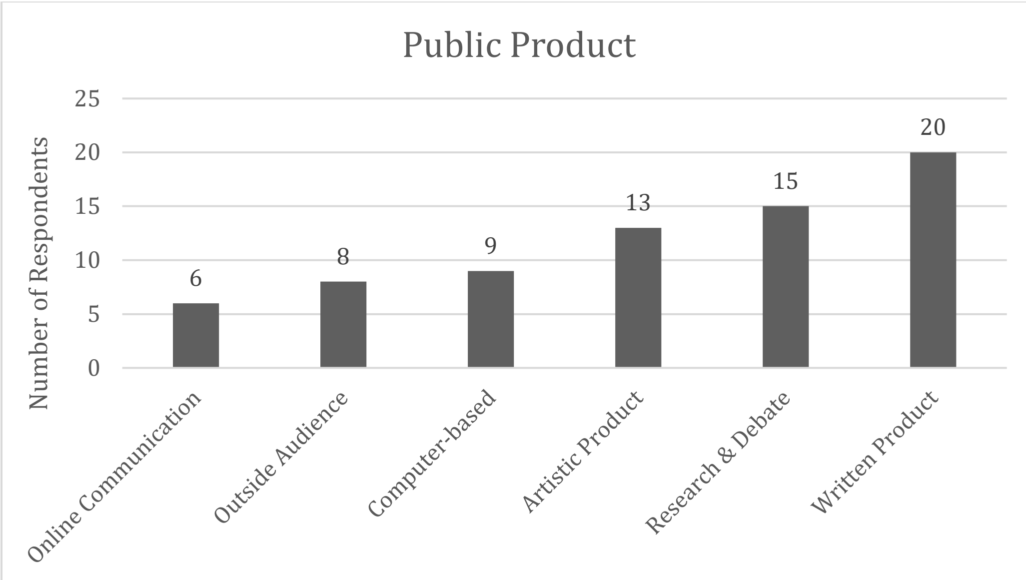
Public Product

Public Product and *Authenticity* are linked in the Gold Standard PBL Design Elements. By public audience, it is meant that the student applies what has been learned outside of themselves or outside of the classroom. This important aspect of PBL requires that students be given opportunities to discuss what they have learned as well as to discuss the processes with which they engaged in the during learning. This study supports the importance of a public product and has been cited by a number of researchers including Arantes do Amaral et al., (2015), Boss and Larmer, (2018) Grant, (2011), and PBL Works (2022).

In this questionnaire, the most common public product described by the teachers was the presentation of a written product (80%). Next in frequency were demonstrations of research and debate (60%) and artistic product/presentations (52%). Additional public products included computer-based artifacts (36%) presentations to audiences in other schools or professional experts (32%) and communicating via the Internet in various online applications (24%), as shown in Figure 3.

Figure 3

PBL Gold Standard Design Element, Public Products Used by Teachers (n=25)



Teacher Preparedness to Use Essential Product Design Elements and Project-based Teaching Practices for Gold Standard PBL

PBL requires multiple opportunities for the student to engage in sustained inquiry. Specifically, "Students engage in a rigorous, extended process of posing questions, finding resources, and applying information" (PBL Works, 2022). All teachers stated they felt *somewhat prepared* (11) or *well-prepared* (14) to promote depth or quality in student work during projects. As stated earlier, as part of their pre-service teacher training, a PBL unit was developed and implemented in a secondary school setting. This unit also aligns with CAEP accreditation artifacts, and as such, the pre-service teacher is provided with extensive feedback involving critique and revision during planning and design. Pre-service teachers practiced the lesson with a peer and a content area coach, and ultimately taught the lesson to public school students under supervision.

Sustained Inquiry, which is one of the essential PBL design elements, was stated as a challenge to implementation of PBL (Table 2), although the teachers indicated preparedness to have their students engage in a "rigorous, extended process of posing questions, finding resources, and applying information," as shown in Table 4.

Table 4

Average Item Response for Teacher Preparedness for Mean, Standard Deviation, Median and Mode

Practice	PBL Element #	Mean	SD	Median	Mode
Sustained Inquiry [a]	2	2.56	0.51	3	3
Design and Plan [b]	2	2.48	0.59	3	3
Design and Plan [b]	2	2.48	0.51	2	2
Align to Standards [b]	3	2.44	0.58	2	2
Manage Activities [b]	4	2.68	0.48	3	3
Manage Activities [b]	4	2.32	0.48	2	2
Assess Student Learning [b]	5	2.44	0.58	2	3
Assess Student Learning [b]	5	2.64	0.49	3	3

Note. n = 25; A 3-point Likert Scale was used (1 =not prepared; 2=somewhat prepared; 3=well-prepared).

[a] PBL Gold Standard Product Design Elements.
[b] PBL Gold Standard Project-based Teaching Practices.

That is, the teachers indicate they are prepared, but the challenges for implementation in the classroom are weighty due to challenges such as short class periods, student behavior, and lack of resources. As time is a variable that challenges implementation of PBL, it is possible that teachers have the expertise to facilitate inquiry, but feel they lack the time in the curriculum to do so. The mean score for teacher preparedness to promote sustained inquiry was 2.56 on a 3-point scale.

One of the Gold Standard PBL Teaching Practices is the *Design & Plan* of projects. As shown in Table 4 most teachers felt prepared to design and plan lessons, indicating they wanted to make teaching and learning more varied, challenging, or fun as well as create lessons to convey academic content knowledge and skills more effectively. Mean scores for two questionnaire items were 2.48 and 2.48 respectively with median scores of 3 and 2 respectively. That is, the teachers indicated they were prepared for *Design and Plan* PBL teaching practices. Two questionnaire items addressed preparedness to design and plan lessons (i.e., find existing project of high quality and plan and design new projects). When conducting projects, teachers developed a detailed overall plan describing the project from start to finish using artifacts such as templates, checklists, timelines, and project maps. However, novice teachers felt less prepared using PBL to meet district standards or state standards due to a school emphasis on benchmark and state testing (M = 2.44; Median = 2).

Teachers indicated they felt either *somewhat prepared* to *well-prepared* for the Gold Standard PBL Teaching Practice, *Manage Activities*. Two items addressed included promoting and supporting students' group work and structuring presentations in ways that encourage whole class learning. In particular, most teachers considered themselves well-prepared regarding the facilitation and management of students' work in groups (M = 2.68; Median = 3) and somewhat prepared in the creation of products made public (M = 2.48 Median = 2).

All participants indicated preparedness for the Gold Standard PBL Teaching Practice, *Assess Student Learning*. Three items addressed preparedness to assess content (M = 2.44; Median = 2) and assess group work. Rubrics were used to guide students and to assess projects for content accuracy, thoroughness, or depth of understanding. Formative assessment included short-term assessments such as *Just in Time Formative Assessments* (occurring in class that day), together with *Diagnostic Formative Assessments* (to identify student strengths and weaknesses) *and Medium-Cycle Formative Assessments* (i.e., project assessment, unit assessment).

Teaching Approaches Associated with PBL

There is a continuum of approaches with regard to the role of the teacher in PBL. Some aspects of instruction, such as the introduction to PBL may involve direct instruction, while other aspects are more oriented toward types of inquiry. Whichever approach is used, it should make the most of the learning time, removing bottlenecks to learning, allowing for differentiation, reflection, and sometimes just going with the flow (Boss & Larmer, 2018; PBL Works, 2022). The mean for a flexible approach was 3.63 with a median and mode of four while the mean for direct instruction was 3.16 with a median and mode of three. Specifically, fifteen teachers (60%) indicated they used a flexible approach *most of the time* or *all of the time*, while eight teachers (32%) used direct instruction *most of the time* or *all of the time*. Team teaching and interdisciplinary projects were *not at all* used or *sometimes* used. These practices suggest the teachers emphasized on the use of inquiry, but also used direct instruction as instructional models. This information is shown in Table 5.

Table 5

Average Item Response by Teaching Approaches Used with Mean, Standard Deviations, Median and Modes (n=25)

Teaching Strategy	Mean	SD	Median	Mode
Direct Instruction	3.16	0.80	3	3
Flexible approach	3.63	0.88	4	4
Team teaching	1.56	0.58	2	2
Interdisciplinary projects	1.76	0.66	2	2

Note. A 5-point Likert Scale was used (1=not at all; 2=sometimes; 3=half the time; 4=most of the time; 5=all the time).

Conclusions

PBL has been shown to develop critical thinking skills, promote deep learning, and encourage self-directed learning (Larmer, 2015). Additionally, the use of PBL has been shown to enhance collaboration, motivation, integration of knowledge, and the preparation of the student for real-world challenges (Larmer, 2015). Instead of focusing on rote learning and memorization, the learning shifts to understanding and the application of knowledge though a process of self-directed learning. Such experiences should better prepare students for the job market though encouragement of creativity and innovating to promote economic growth and meeting local and national challenges. For this reason, this program and other UTeach replication programs across the United States have as a part of the curriculum a course in PBL that includes not only classroom instruction, but also extensive field experiences in schools that utilize PBL. Within this model, instructors act as facilitators and feedback, most notably a recursive cycle of reflective practice is common.

This study examined secondary science and mathematics teacher knowledge of and beliefs about PBL design elements and teaching practices. Of 96 respondents, 25 teachers completed the questionnaire and indicated they used PBL as an approach to learning. Response to the questionnaire was good with 96 out of 138 responding. Still, the frequency of PBL use in the classroom (25% or less of instructional time), school district support for PBL (half-day or less of professional development) and the number of respondents who used PBL in their classroom (26%) is disappointing given the 70 hours of instructional time dedicated in the course. More so as it is a core course, as well as the significant field experiences that took place in PBL settings the use of PBL in the classroom is underwhelming. Also, 76% of teachers indicated they work in schools that emphasize 21st century skills, so it is unclear what other approaches are used to acquaint students with these skills.

The rationale for use of PBL (i.e., fun, teach academic content, teach 21st century skills) and the challenges associated with its use (i.e., funding, accountability requirements, time constraints) echo that of previous researchers. However, we found teacher beliefs about the effectiveness of PBL to teach low-achieving students was contrary to research findings which show PBL to be at least the same as other approaches with regard to achievement. It is interesting that the teachers agreed that PBL helped with motivation and with students who have limited English skills.

With regard to preparedness to teach PBL, the teachers indicated they felt *somewhat* or *well-prepared* to use the Gold Standard PBL design elements and teaching practices. Results showed teachers believed they were prepared to use sustained inquiry (i.e., promote depth and quality), authenticity (i.e., observation, simulation) assessment (i.e., individual and group assessment), design/plan (i.ge, find high quality projects, plan/design new projects), manage activities (i.e., group work, class presentations) and facilitate public presentations outside the classroom (e.g., I*EARN, Project Globe, performance, brochures). Given the prior experiences as pre-service teachers, those teachers using PBL demonstrated good knowledge of the Gold Standard Design Elements and Teaching Practices.

Implications

Secondary mathematics and science teachers in this study displayed knowledge of the Gold Standard Design Elements and Teaching Practices of PBL and indicated they felt prepared, to some extent, to facilitate PBL in their classrooms. A majority of the teachers used inquiry as well as direct instruction as dominant models of teaching within PBL and emphasized their belief that flexible instruction is important to achieve fidelity to the approach. However, in this study, only about 25% of the total respondents (n=93) indicated they used PBL in the classroom, and 68% of these teachers (17/25) used this approach less than 26% of their instructional time.

PBL is a core course in UTeach replication sites across the United States (>50 sites). More research into the comparison of various programs graduate's use of PBL in their classroom once they become classroom teachers is also warranted.

Limitations

Compared to other programs in the United States, this program is among those producing a large number of high-quality mathematics and science teachers who have been well prepared in both content and pedagogy. However, compared to the need for high-quality teachers, these numbers are inadequate. Marder (2020) and also Landa (2024) addressed the inadequate teacher pipeline. Thus, while this study represents a large program in the United States, the sample is small but remains an important research setting.

Although challenges to implementation of PBL were identified by the teachers, more research is needed to fully understand the challenges that prevent teachers from spending time using this approach to its fullest potential. In addition, more research is needed to address questions such as: "At what point do teachers believe classes are too large to implement PBL? How can the negative role of accountability requirements be addressed? When and what ways should students acquire skills to take full advantage of PBL?"

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