Article

Exploring Relationships between Professional Development and Teachers' Enactments of Project-Based Learning

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Abstract: This paper examines whether teachers' prior professional development (PD) in Project-Based Learning (PBL) significantly related to teachers' enactments of PBL practices within the classroom. Teachers (N = 40) were recruited based on their commitment to enacting PBL in their classrooms. Teachers were surveyed regarding the extent to which they had experienced prior PD in PBL and asked to submit two videos of their classroom instruction. Videos were coded according to teachers' quality enactment of PBL practices during instruction. Results suggest that teachers who had prior PD in PBL enacted more structure-driven PBL practices (e.g., setting up and managing projects) and incorporated more collaboration practices. However, for other purpose-driven practices of PBL (e.g., supporting student choice, supporting students to make personal connections), teachers with prior PD were no different from teachers without prior PD. The results suggest that teachers may need more intensive and fine-grained, practice-based PD in purpose-driven PBL practices.

Keywords: project-based learning; professional development; teacher practice

1. Introduction

Student-centered learning, an inquiry-based approach in which students are active participants, has recently been the focus of many educational reform efforts that make promises to radically transform the educational experiences of students. In 2019, for example, the Council of Chief State School Officers published a resource bank on student-centered learning (and the National Council of State Legislators developed a bipartisan commission of state legislators to study legislative policy options to "help states move forward with systems that support student-centered learning opportunities" [1].

This shift toward student-centered learning in policy circles stands in contrast to teacher-centered approaches to learning, or what Freire calls "the banking method of education" [2]. These teacher-centered approaches to learning understand the teacher as the holder of expert knowledge that can be transferred to students. Such teacher-centered approaches are often critiqued for narrowly focusing on decontextualized skills aligned to high-stakes standardized tests [3]. These teacher-centered approaches, some argue, can focus too heavily on lower-level skills, such as rote memorization and identification, neglecting a wide range of skills, such as communication and collaboration skills, decision-making, problem-solving, critical-thinking, and self-directed learning, which are necessary for long term academic achievement [4,5]. To counteract an overemphasis upon skill acquisition, student-centered pedagogies attempt to place students at the center of learning through active, inquiry-based approaches. The teacher does not direct or control learning, but rather facilitates, allowing students control over their learning processes [5]. Thus, a student-centered pedagogy is believed to promote educational experiences that connect to student interests to foster deep, meaningful learning [6,7].

Unfortunately, access to student-centered approaches to learning is not equitably distributed [8–10]. This inequitable distribution of instructional approaches is a central part of what Ladson-Billings has termed the "opportunity gap" [11] and is buoyed by policies and curricula that promote rote and decontextualized instruction for students of color and students impacted by poverty [3,12]). Such policies and curricula, together with the legacies of racial oppression, have meant that white and affluent students often have greater access to authentic, student-centered instruction [13]. Broadening access to student-centered approaches to instruction may, therefore, be an important component of broader efforts to promote educational equity.

While contemporary reformers and leaders have begun to speak more frequently about "student-centered" approaches generally, there is one student-centered approach that has taken center stage in contemporary conversations: "Project-Based Learning" or PBL. PBL has begun to garner significant attention from policy makers, educational leaders, and educational reformers [14]. While PBL may be a promising student-centered approach, little is known about how best to support teachers' enactment of core PBL practices within the dynamic of a classroom. That is, we do not know which approaches to PBL professional development significantly influence teachers' implementations of PBL. This is an important consideration, because, ultimately, successful implementation of any intervention resides in teachers' enactments of the practices aligned to the goals of the initiative [15]. As such, the promise of PBL hinges on teachers' ability to enact classroom practices that align with PBL. However, supporting changes in teacher practice is a complex endeavor [9]. In this research, we have identified teacher practices that are aligned to the underlying goals of Project-Based Learning so that we can explore relationships between typical approaches to PBL professional development (PD) and teachers' enactments of core PBL practices. These findings can help to inform future PD to better meet needs of teachers as they extend knowledge to practice.

2. Project-Based Learning

Project-Based Learning (PBL) is an approach to teaching that organizes the activity of learners around projects rather than tests. Projects are designed to engage learners in meaningful activity that culminates in the production of authentic work that is shared in the form of a public product with a real audience [7,16]. In high quality project-based learning, work on projects requires meaningful disciplinary, or interdisciplinary, inquiry, through which learners gain both skills and knowledge. Proponents argue that this form of learning develops students' intrinsic motivation, problem-solving skills, and independence [17]. While contemporary PBL frameworks can draw their roots back many decades, they are also uniquely of the moment. Definitions of PBL vary, but most share a set of overlapping criteria:

- projects are driven by real-world, authentic questions;
- they engage students in rigorous, sustained inquiry;
- they offer students voice, choice, and agency in collaborative learning environments;
- they provide multiple opportunities for reflection, revision, and assessment;
- they culminate in a public production to an authentic audience.

While there are certainly differences across definitions of project-based learning, these criteria, in some form, are foundational to all PBL design principles [18].

Building off of these common attributes of PBL frameworks, Grossman and colleagues proposed four distinct, yet intertwined, goals of PBL: Disciplinary rigor, Authentic tasks, Iterative processes and Collaborative activity [19]. Grounded in these goals, PBL classrooms provide an inquiry-based context, and a project, whereby students are provided with experiences with real-world dilemmas, which are personally relevant. Students collaboratively explore viable solutions as they construct their own knowledge, pursuing choices that come from their lived experiences and understandings. Finally, students' unique solutions are presented as a product to their surrounding communities. In the process, students develop disciplinary processes, higher order thinking skills, and critical knowledge, such as analysis

and judgment of diverse perspectives. Therefore, some of the allure of PBL is attributable to providing students with opportunities to develop 21st century skills, such as interpersonal and problem-solving skills, that extend beyond school [20]. Specifically, in this current research, we have identified teacher practices that support 1/a PBL-focus and 2/the four underlying goals of effective Project-Based Learning instruction [19] (See Table 1).

Table 1. Key PBL Goals and Corresponding Practices.

	PBL Goals	**Practices**
Structure-Driven	Project-Focus	Engage students in work on projects Explain project expectations Connect lesson components to the project
Purpose-Driven	Disciplinary	Engage students in disciplinary practices (i.e., disciplinary inquiry and disciplinary talk)
	Collaboration	Support students to collaborate Support students to make choices
	Authenticity	Support students to build personal connections to their work Support students to make a contribution to their world
	Iteration	Support students to give and receive feedback Support students to reflect and revise

3. PBL Focus: Structure-Driven Practices

As the name implies, PBL focus practices maintain attention to the project, while making connections between components and relaying expectations of student-driven inquiry within the classroom. Thus, PBL focus practices are more structure-driven, in that these practices promote managing and organizing student inquiry. In this research, we have identified three PBL focus practices: *engage students to work on projects*, *explain project expectations*, and *connect lesson components to the project*. While essential, these practices are not necessarily focused on the higher, overarching goals of PBL which drive successful implementation.

4. PBL Purpose-Driven Practices

PBL purpose-driven practices are categorized according to the four main goals of PBL: Disciplinary, Authenticity, Iteration, and Collaboration [19].

Disciplinary. Disciplinary goals focus on facilitating students' involvement with the thinking, processes, and practices of disciplinarians and related professionals. In this way, high quality PBL instruction includes teacher *support of students' active engagement with disciplinary practices*. Teachers support students' disciplinary inquiry and talk in the service of solving real-world problems related to a subject area. That is, students construct knowledge through inquiry, which recruits higher order thinking processes. At the same time, students come to see the utility of traditional subjects, because disciplinary learning goals encompass solving real-world problems in the service of surrounding communities.

Authenticity. As noted, PBL goals entail supporting students' connections to the process of their unique construction of knowledge to be shared with an authentic audience. Authentic teacher practices (1) *support students to build personal connections to their work*, and (2) *support students to make a contribution to the world*. Authentic goals help foster student motivation to engage in complex tasks associated with disciplinary learning. Thus, another major goal of PBL are collaborative and iterative processes.

Iteration. Iterative processes facilitate students' meaning making and tap into students' analysis, synthesis, and judgement of content in the service of problem-solving. Quality interaction teacher practices examined in the current research are (1) *support students to give and receive feedback*, and (2) *support students' reflection and revision*.

Collaboration. Finally, collaborative processes involve students working together as they grapple with real-world problems. Teachers (1) support students to collaborate

effectively and (2) support students' team choices through the process. The underlying goals of collaboration are to develop interpersonal skill sets that are readily transferable to other real-world disciplinary inquiry contexts.

As described, the overarching goals of PBL are the underlying purposes of teacher practices. In the hands of excellent teachers, these purpose-driven practices are intricately interwoven to create very different learning experiences for students that, ultimately, propel students toward greater academic achievement, because the student is placed at the center of learning. However, the success of PBL implementation within classrooms ultimately relies on teacher practices because, in the end, teachers are the driving force behind implementation.

5. Teaching Practices

Teachers are the most important in-school factor in student achievement [20]. Although an underlying goal of PBL is for students to construct their own knowledge through the context of authentic projects, teachers are essential to provide the guidance and feedback necessary to make PBL a success [21]. The PBL pedagogical shift from a traditional teacher-centered approach (e.g., teacher as authority) to a student-centered one (e.g., teacher as facilitator) is a challenging transition [18].

First, the demands of a student-centered approach require a significant amount of planning and precision in executing strategies that would facilitate, rather than control, student learning. Teaching is challenging in the best of circumstances but adding in the burden of creating and planning real-world projects adds some tension in that now teachers must also simultaneously consider students' interests and technological resources that are needed to provide real-world contexts, and teachers' accessibility to, and skills with, technological resources may be limited [22]. These challenges may be considered on a design or curricular level. Yet, even quality PBL curriculums are limited in their success to truly change teachers' approach to instruction [23]. While a quality curriculum may be an important conduit from theory to practice, teachers need explicit representations of what quality PBL practices look like in the classroom [19]. As such, yet another hurdle to quality PBL instruction is on the spot interactions, supports, and scaffolds for active learning within the classroom environment.

As students engage in active discovery, teachers must be able to challenge and change students' initial misunderstandings to support learning [24]. Thus, enactment of quality PBL practices may also entail a considerable amount of knowledge, both of students' initial skill levels and the abilities that they bring to learning experiences, and pedagogical knowledge to support learners as they move further on the next zone of proximal development [25]. Indeed, teacher knowledge of both the subject content and pedagogical content have been shown to link to academic achievement [26]. and likewise would be necessary to successfully implement PBL, especially considering the ambiguity in classroom activity driven by student inquiry.

Student-centered classrooms involve the teacher foregoing control, which means allowing a certain amount of spontaneity and on the spot restructuring of lessons and activities to allow for student exploration. The unknown involved in a student-centered approach can be quite unnerving, especially coupled with the fact that many teachers are up against time constraints and pressure to meet certain standards for high-stakes tests. The demands of PBL pedagogies have been shown to frustrate novice teachers, in particular, and are likely to frustrate teachers new to such a drastic shift in teacher practices [27]. If teachers are confronted with such implementation challenges, it becomes difficult to weave PBL goals into their existing pedagogical schema of "best practices", developed through practical experiences that form belief systems.

Pedagogy is guided by orientations or beliefs. As a result, teachers' practices, consequently, may be more resistant to change [28]. If teachers do not embrace the ideas of constructivism, student-centered learning, their practices are likely to reflect a more traditional approach despite a curriculum that includes projects. Even if teachers' orientations

and beliefs align with project-based learning, changing behavior that is entrenched in utility is extremely challenging. Change entails new trial and error halting forward motion in replacement of a previous smooth, planned out journey through a unit. Therefore, enacting new practices means that even experienced teachers become novices again.

In sum, a PBL approach in the classroom does not guarantee quality PBL instruction. A host of challenges emerge for teachers' successful implementation. Therefore, it is important to turn attention to supporting teachers, through effective PD, because a) teachers are the key to unlock quality learning experiences through their enactment of core PBL practices and b) teachers need support in their shift towards PBL, student-centered, instructional practices within the classroom.

6. Professional Development

A way to support teachers in their implementation of PBL is providing professional development [29,30]). Researchers, for example, have noted that simply adopting a project-based curriculum is not enough [31,32]). Curriculum, devoid of related ongoing support of teachers in its implementation, has limited capacity to be effective. Therefore, it is of critical importance to attend to the learning needs of teachers through professional development, because teachers are the exclusive vehicle through which curriculum is delivered to students.

Professional development can provide a variety of learning activities to support teachers in applying what they are learning to their own practice and to resolving problems they are experiencing in their own classrooms. Thus, through PD, teachers are given a space in which to work out their knowledge of a particular program and its goals to connect to the practicality they experience within the classroom. In this way, professional development may help teachers develop concurrent practices aligned to the goals of specific programs, in this case PBL.

For example, Kanter & Konstantopoulos provided nine science teachers in an urban district with a PBL-centered curriculum [24]. Additionally, they also included what they termed a practice-based approach to professional development, specifically focused on analyzing students' thinking. The aim was to increase teachers' ability to use their conceptual knowledge of science to increase their guidance of students in productive conversations that would clarify and change student ideas, as opposed to using the PBL curriculum to help students get the right answer. Results indicated that after receiving professional development, teachers used more strategies to encourage and challenge thinking of science concepts with significant effect from pre-post teacher-practice enactment scores during interactions with students. Consequently, teachers' changes in practice impacted marginalized students' science achievement scores. Thus, professional development may support teachers to connect knowledge to practice, which can positively impact teachers' attitudes towards embracing [33]. If teachers believe that PBL can work within their classrooms because they see a pathway toward (a) enactment and (b) successful outcomes for students, they will be more likely to implement PBL effectively.

However, limits of PD have continuously been highlighted [30,34,35] (While the underlying belief of professional development is that it will impact teacher practice in the classroom and, consequently, the quality of education provided to students, the transfer of theory to practice requires attention, not just to what teachers are learning, but to how they are learning [30]. Much of the research analyzing PD effectiveness seems to underscore that an integral part of successful PD are the ways teachers engage with new knowledge at both an individual and group level [30,36,37]). That is, teachers need to be provided with opportunities to stretch their understanding in ways that motivate them to engage with new practices within the classroom [37,38]. Yet, professional development designs vary considerably in regard to the types of opportunities teachers have to engage with new pedagogies [30]. In regard to project-based learning, specifically, teachers must shift to a student-centered pedagogy that requires foregoing their customary practices in lieu of different practices that many teachers will find diametrically opposed to their normal

way of teaching [27]. Thus, teachers' engagement with a new pedagogy requires more than adoption of new practices, for teachers have developed their practical pedagogies in response to their classroom experiences [28,30] This means teachers are accustomed to teaching and responding to students in a certain way. By abandoning old practices for different ones, teachers essentially open themselves to the vulnerability of having less control, and in many ways regress to the level of novice teacher as they try out different practices [27,30].

As a result, many teachers need time, encouragement, and space to practice and reflect on enactment of pedagogy [39,40]. Research seems to suggest that for teachers to be successful in their enactment of PBL practices, a considerable amount of time and attention to supporting teachers is needed, usually beyond normal limits of school allocations for PD [39,41,42]. In light of these findings, there is a need to explore whether PD focused on support for PBL implementation is changing the type of learning experiences being offered to students. Can professional development be enough to truly bring about such a momentous change in teaching practices?

7. Aims of the Current Study

Questions remain as to the role that typical approaches to PD play in teachers' enactment of PBL. PBL is structured around the project as a vehicle for students to become active participants. Yet, the quality of PBL implementation has, at its core, a purpose-driven framework focused on Disciplinary rigor, Authentic tasks, Collaborative activity, and Iterative processes [19]. However, we currently do not yet understand how, or to what degree, typical approaches to PBL PD impact teachers' specific practices related to quality PBL instruction. This is an important consideration for developing PD for project-based learning. Understanding areas within project-based learning where teachers may need further support will help enable PD developers to tailor programs to more fully focus on the challenging aspects involved in teacher enactment of PBL practices within the classroom. As such we ask the following questions:

Q1. What aspects of PBL practice are most, and least, related to having experienced prior professional development focused on project-based learning?

Q2. Is having experienced PBL-specific professional development predictive of classroom practice associated with PBL?

8. Methods

8.1. Participants

Participants were N = 40 teachers from middle school (n = 13) and high school (n = 27). Of those 40 teachers 47.5% reported not having had past professional development in PBL, but 52.5% reported having had prior PBL training (See Table 2). The majority of participants were female, 67.5% and White, 57.5%. The subject area that teachers taught was evenly distributed with around half (n = 21) teaching a science course, and the other half (n = 19) teaching a humanities course. Most teachers had at least a bachelor's degree in their subject area discipline (67.5%), but 32.5% did not. Additionally, 57.5% of participants held a master's degree in Education, while 42.5% did not. Selection criteria for the study are discussed in the procedures below.

Table 2. Sample Characteristics with Chi-Square Analyses to Examine Differences by PD Status.

	Total N = 40		Prior-PD n = 21		No-PD n = 19		
	n	**%**	**n**	**%**	**n**	**%**	**χ2**
Race							5.11
White	23	57.5%	10	48%	13	68.5%	
African American	6	15%	4	19%	2	10.5%	
Hispanic	4	10%	4	19%	0	0%	
Asian	7	17.5%	3	14%	4	21%	
Gender							0.31
Male	13	32.5%	6	31.5%	7	43%	
Female	27	67.5%	15	68.5%	12	57%	
Grade							0.31
Middle School	13	32.5%	6	31.5%	7	43%	
High School	27	67.5%	15	68.5%	12	57%	
Subject Taught							0
Science	21	52.5%	11	52%	10	52.5%	
Humanities	19	47.5%	10	48%	9	47.5%	
Courses in Discipline							6.72
Little to none	0	0%	0	0%	0	0%	
Some undergraduate	8	20%	3	14.3%	5	26%	
Undergraduate minor	5	12.5%	4	19.05%	1	5.5%	
Undergraduate Major	18	45%	7	33.3%	11	58%	
Some graduate	6	15%	4	19.05%	2	10.5%	
Graduate Degree	3	7.5%	3	14.3%	0	0%	
Courses in Education							8.65
Little to none	1	2.5%	1	4.5%	0	0%	
Some undergraduate	2	5%	0	0%	2	10.5%	
Undergraduate minor	2	5%	0	0%	2	10.5%	
Undergraduate Major	6	15%	2	9.5%	4	21%	
Some graduate	6	15%	5	24%	1	5%	
Graduate Degree	23	57.5%	13	62%	10	53%	

8.2. Procedure

Recruitment and Inclusion. We used a multi-stage process to select participants. The participants were selected from a cadre of teachers that had enrolled in (but had not yet begun) a certificate program in a graduate school of education in the northeastern region of the United States. The program they were enrolled in focused on developing instructional practices specific to project-based learning. However, at the time of data collection, none of the teachers had begun this program. A subsample of teachers had previously responded to a call for teachers who had interest and some experience in project-based learning. We next analyzed the teachers' responses to the questionnaire/application to determine their self-reported intentions and any experience or past knowledge of Project-Based Learning. Specifically, survey questions were used to determine the degree to which respondents (a) incorporated PBL in their classrooms, (b) had engaged in professional learning around PBL instruction, and (c) articulated a commitment to ongoing professional learning.

Teachers were selected for the study based on their similarity in grade span and subject area focus as well as the fact that their application responses illustrated that they had some knowledge of PBL, along with a commitment to ongoing professional development.

Study Procedure. Teachers who met initial criteria were next asked to complete a brief survey inclusive of their prior teaching experience, PBL professional development experience, credentials, and demographic information, such as age, race, gender. Final participants, in addition to providing consent and their surveys, were also asked to submit two videos of themselves teaching PBL lessons from a project in their classrooms in the spring of the school year.

8.3. Measures

Teacher Videos. We assessed teachers' enactment of PBL teaching practices through coding two videos submitted by each teacher. Videos of teachers were coded using the Penn PBL Video Observation Protocol—a systematic observation coding tool focused on capturing distinct practices in providing quality PBL instruction. The protocol was framed around the 4 core goals of PBL (i.e., Disciplinary, Authenticity, Iteration, and Collaboration). For each goal, we explored corresponding core practices and sub-practices (See Table 1). For teachers who provided two videos of their PBL classroom instruction, n = 29, we averaged the two video scores for each item into one composite score. There were 11 teachers with only one video score. Teachers received a total of 11 PBL practice-item scores.

Video Scoring and Reliability. Videos were scored independently by two graduate students rigorously trained by the second researcher. Scores for each item range from 1 (provides almost no evidence), to 4 (provides consistent strong evidence). Videos were double scored to ensure high levels of ongoing inter-rater agreement. Ten percent of videos were randomly chosen and an inter-rater reliability analysis, using the weighted Kappa statistic, was performed to determine consistency among raters (See Table 1). Across the 12 items, raters reached substantial agreement, weighted Kappa = 0.631–0.922, $p < 0.001$, for all items [43].

Survey. Teachers were asked to take a survey in which questions about their demographic (e.g., gender) and background variables (e.g., educational level) were used for this study. As noted in our recruitment procedures, teachers in this sample were motivated to improve practices specifically related to PBL. For example, when asked to what extent teachers were committed to improving their practice, all teachers indicated that they were "very" to "extremely" committed to improving their practice. Teachers' enthusiasm to improve practice did not differ as a function of having had prior professional development in PBL. $F(1, 38) = 0.02$, $p = 0.898$. As such, both groups of teachers were comparative in their motivation to learn, which is important when considering effects of PD on teachers' practices, in particular [30].

Experience with PBL. Of specific interest to this study, was whether or not teachers had completed prior professional development related to PBL. Thus, teachers were also asked if they had any past professional development that focused on project-based learning. We used teachers' self-reported previous professional development experience with project-based learning to determine which teachers had undergone prior PBL training and those teachers who had not.

In exploring the types of PD teachers had, we analyzed teacher open-ended responses detailing specifics of their PD. We found that teachers' professional development experiences varied. Some underwent district PD that may have involved one to a few sessions; others indicated enrolling in a PD program lasting months to up to two years. Still others gave no specification of the type of PD they had undertaken.

In order to assess the extent to which all teachers had experience with PBL, teachers answered a question in which they were able to identify all listed experiences that applied to them as well as write in other experiences. In looking through these responses, some teachers identified pre-service or graduate courses in education. Others indicated that they had done their own research and read articles about PBL. Some indicated that PBL was a focal point of their school, and their experiences came from administration or collegial support in PBL. Importantly, all teachers in our sample had some experience with PBL and willingly enrolled in our program to increase their efficacy in enacting PBL in their classrooms. For example, within the survey, teachers were asked to indicate the frequency of their incorporation of PBL within their classroom instruction. For this survey item, teachers answered on a scale of 1 = Never to 7 = Every day. The mean score for this item was 4.85, indicating that on average teachers in this sample used PBL in their classrooms about once every few weeks to once a week. To further probe whether there were differences between teachers who did have prior PD and those who did not, we used a one-way ANOVA test. Results showed that teachers who had prior PD in PBL had a higher mean score in the

self-reported frequency at which they used PBL in their classrooms (M = 5.38, SD = 1.90, range = 1–7), whereas the mean score for teachers who did not have prior PD was 4.26 (SD = 1.93, range = 1–7), and this difference was approaching significance $F(1, 38)$ = 3.37, p = 0.074. That is, teachers who had prior PD enacted PBL instruction in their classrooms somewhat more than teachers who did not, but the difference did not reach the level of significance.

Additionally, most teachers felt confident to very confident in providing instruction in PBL. As with teachers' motivation to learn, we found teachers' confidence in enacting PBL in their classrooms did not differ between teachers who had prior PD from those teachers who did not have prior PD in PBL. Thus, teachers' self-efficacy at enacting PBL was comparable between teacher groups, which is important when considering teachers' classroom enactment of practices [36].

Background variables. Finally, the surveys collected information about teachers' educational levels in both their subject areas and their training in education programs (i.e., 1 = little to no undergraduate level courses to 6 = graduate degree). Teachers' knowledge of both the subject content and pedagogical content may be important to enactment of PBL practices within the classroom [26]. We also collected survey information about the grade level teachers taught (0 = middle school; 1 = high school) and the subject taught (0 = humanities; 1 = science) that were used in some analyses.

9. Results

9.1. Q1. Relation between Teachers PBL Practices and Their Having Experienced Prior PD in PBL

We first determined whether PBL practices would be enacted in a stronger manner by teachers who had previously participated in PD on PBL, compared to those who had not. Mean scores of teachers' observed practice ratings on the scale of 1-4 across the 12 items by PD status are shown in Table 3.

Table 3. Mean Scores and Comparisons of PBL Practices by PD Status.

PBL Practice	Kappa	Prior PD (*n* = 21)		No PD (*n* = 19)		Prior PD vs. No PD	
		M	**SD**	**M**	**SD**	**F**	**P**
Project-Engage	0.89	2.59	0.82	1.79	0.84	9.48	0.004 **
Project Expectations	0.92	2.43	0.79	1.79	0.75	6.79	0.013 *
Project Components	0.91	2.57	1.09	1.79	1.01	5.55	0.024 *
Disciplinary Inquiry	0.77	2.21	1.11	2.11	0.66	0.14	0.712
Disciplinary Talk	0.73	2.76	0.96	2.39	0.57	2.08	0.158
Personal Connections	0.63	1.30	0.69	1.24	0.39	0.16	0.690
Audience Contribution	1	1.00	0.00	1.08	0.25	2.09	0.157
Student Reflection and Revision	0.70	1.28	1.11	1.08	0.34	2.99	0.096
Peer Feedback	0.81	1.11	1.28	1.05	0.23	0.58	0.452
Collaboration	0.73	2.19	0.95	1.50	0.69	6.76	0.013 *
Student Choice	0.64	1.61	0.75	1.32	0.56	2.04	0.161

Note. * indicates $p < 0.05$; ** indicates $p < 0.01$.

One-way ANOVAs revealed that compared to teachers with no prior PD on PBL, teachers who had past professional development in PBL worked more on projects, $F(1, 38)$ = 9.48, p = 0.004, provided clearer project expectations, $F(1, 38)$ = 6.79, p = 0.013, and connected the project to the specific lesson, $F(1, 38)$ = 5.55, p = 0.024. Additionally, PD teachers' had students collaborate significantly more on projects relative to those teachers without prior PD, $F(1,38)$ = 6.759, p = 0.013. There were no significant differences between teachers who had or had not had previous PBL PD experiences for the remaining seven teacher practice items (See Table 2). Overall, teachers performed significantly better on 4 of the 11 PBL practices if they had previously completed a PBL professional development course than if they had not had prior professional development in PBL. Additionally, 3 of the 4 practices

were all related to a structure-driven goal, rather than the purpose-driven goals that are at the core of PBL.

9.2. Q2. PD as a Predictor of PBL Teaching Practices

Next, Ordinary Least Squares Regression was used to explore the predictive nature of teachers' prior professional development for each of the four teaching practices showing significant differences in mean scores: teachers' enactment of projects within the classroom, teachers' explanations of project expectations, teachers' connections between lessons to the project, and teachers' incorporation of collaboration, net of the effect of teacher background factors and other control variables (See Table 4).

Table 4. Multiple Regression Models Predicting Teacher PBL Practices Accounting for Prior PD Status.

	PBL Practices (Standardized β).			
	Model 1 (Project-Engage)	**Model 2 (Expectations)**	**Model 3 (Components)**	**Model 4 (Collaboration)**
Subject Taught	0.08	0.10	−0.11	0.01
Grade	0.17	0.31 *	0.25	−0.06
Disciplinary Ed.	−0.28	−0.28	−0.16	0.04
Education Ed.	0.16	0.42 **	0.21	0.02
Prior PBL PD	0.46 **	0.34 *	0.33 *	0.38 *
R^2	0.178	0.277	0.116	0.031

Note. * indicates $p < 0.05$; ** indicates $p < 0.01$. Education Ed. = amount of education in the Education field; Disciplinary Ed. = amount of education in the discipline of subject taught; Subject Taught = 1-Science, 0-Humanities; Grade = 1-highschool, 0-middle school; Frequency PBL = Prior PD = 1-yes, 0-no.

We constructed four models in which our outcome variables were teaching practice scores for each of the four teacher practice items. Predictor variables for each model, other than PD status, included classroom subject (i.e., science- or humanities-based), grade level (i.e., middle school or high school), amount of education in subject area discipline (e.g., science education for a biology teacher), and amount of training in education (i.e., teacher education program).

In our first model where Work on project video scores were entered as the outcome, results revealed only one predictor: having prior PD uniquely predicted higher scores on Work on projects ($β = 0.456$, $p = 0.005$). The adjusted R^2 for the model was 0.178.

In our second model, video scores for the teacher practice of providing and supporting project expectations were entered as the outcome variable. We found that having prior PD uniquely predicted teachers' Project expectation scores ($β = 0.335$, $p = 0.024$), net of the effect of other variables. Additionally, having higher levels of education training ($β = 0.415$, $p = 0.001$) and teaching a high school course ($β = 0.309$, $p = 0.047$) predicted higher Project expectation scores. The model accounted for 27.7% of the total variance.

In our third model, we entered teachers' video scores for Continuity of project components as our outcome variable. This model accounted for 11.6% of the total variance. Again, we found that having prior professional development predicted higher scores on this structure-driven teaching practice ($β = 0.325$, $p = 0.046$). There were no other predictors for this model.

Lastly, we entered Collaboration video scores as our outcome. Results revealed that having prior professional development was uniquely linked to supporting students collaborating together on projects ($β = 0.383$, $p = 0.026$). There were no other predictors, and the model accounted for only 3.1% of the total variance.

Overall, results indicated that professional development was a significant predictor of four PBL practices, even after controlling for other relevant dimensions, such as subject area, grade level, and teacher education. Additionally, having prior PD in PBL was the most consistent predictor of stronger teaching PBL practices across the four outcomes compared to any other predictors in our models.

10. Limitations of the Study

Our research is limited in that our participants, who self-reported prior PD, underwent different professional developments in project-based learning. As such, it is unclear the time spent in professional development, or the specific focus and procedures of the professional development. It may be that generic professional development opportunities districts offer to their teachers is of a minimal nature (e.g., lacking in time spent) because of financial constraints. Research that has reported successful professional development in regards to changing teacher behavior and, ultimately, student outcomes were very time consuming, requiring commitment across teachers and district leaders. Such endeavors can be very costly and may lack feasibility on a large scale [35,39].

Thus, the lack of teacher growth in key PBL practices may be because of inadequate professional development, but we are unable to determine, with any certainty, the reasons for the lack of growth without further information about teachers' prior professional development programs.

11. Discussion

The aim of the current research was to explore the impact that prior PBL professional development had on teachers' enactment of core PBL teaching practices. We found that teachers who had experienced prior PD in project-based learning scored higher in structure-driven practices and on one purpose-driven practice, supporting students to collaborate. Specifically, teachers who had experienced prior PD in project-based learning used projects, explained expectations of projects, and connected lessons to the projects more so than teachers who had no prior PD in PBL. Additionally, teachers with prior PD incorporated student collaboration on projects to greater extents. Further, these practice scores were uniquely linked to having prior PD, indicating that prior PD led to increases in structure-driven practices and collaboration. However, prior PD in PBL did not seem to affect teachers' Disciplinary, Authenticity, and Iteration practices or the core practice of supporting students to make choices. In sum, teachers who had received prior PD in PBL seemed to be integrating projects into their design of unit lessons but were not yet enacting the purpose-driven goals of PBL: disciplinary rigor, authentic tasks, and iterative processes. In the paragraphs below, the implications of these findings are discussed in turn. Finally, we suggest that to promote deeper instructional transformation, teachers may need to experience PD that focuses *specifically* on teaching practices related to the underlying goals of PBL: raising disciplinary rigor, engaging students in authentic tasks, supporting students' choice and collaboration, and designing iterative processes for student work [19].

At a basic level, our findings suggest that teachers who entered our study having experienced prior PD in PBL were more likely to use projects in their instruction than teachers who had not received prior PD in PBL. However, while they were more likely to use projects, to reference project expectations, and to find ways to connect individual lessons to larger classroom projects, when it came to offering students choice or engaging students in authentic tasks, tasks with disciplinary rigor, or tasks that involved iteration or prototyping, the teachers who had received prior PD PBL were no different from those who had not. This made us wonder whether the approaches to PD that teachers had experienced had supported them to "use projects," but not to transform their instruction so that it reflected the underlying goals of PBL.

The one finding that made us wonder whether prior PD in PBL *had* influenced goal-driven change in teachers' practices was the fact that we found that teachers who had prior PD in project-based learning had higher video scores related to supporting student collaboration. Collaboration practices support students to make decisions together that drive their problem-solving. If prior PD in PBL was leading teachers to make this kind of a change in their instruction, it might indicate that typical approaches to PD in PBL were leading to transformative change in teachers' practices. However, mean scores suggest that although there were significant differences in collaboration scores between teachers who had received prior PD in PBL and those who had not, teachers who had experienced prior

PD only had a mean score of 2.1 in the practice of supporting students to collaborate. A score of 2.1 indicates that teachers were setting up groups of students to complete work rather than having them work individually. However, teachers who received this score were not supporting students to pursue group-worthy and challenging tasks. Had they been doing this, they would have received a 3 or 4 score on the teacher observation protocol. Given the low mean score for collaboration, it seems teachers were organizing groups to collaborate rather than supporting students to engage in collaborative processes to solve problems. Viewed in this way, teachers with prior PD in PBL may have been focusing more on global aspects, such as management and execution of projects, because of the inherent challenges of PBL [22,27].

One such challenge is that project-based learning involves an inquiry-based approach. Students are involved in utilizing concepts and testing out hypotheses to solve a problem. As such, inquiry-based learning involves a certain amount of ambiguity in its scope and sequence because teachers respond to students' needs as they arise [28].. Therefore, lessons need constant adjustment in response to students as they progress in solving problems. Due to the complexity of facilitating PBL, one interpretation for why teachers who had previously received PD in PBL may have only had higher scores in structure-driven practices is that mastering the structure of PBL is a necessary first step towards enacting complex, inquiry-driven, authentic instruction. Perhaps the teachers in our sample were in the early stages of a long developmental trajectory towards sophisticated PBL enactment and the early stages of that trajectory were focused on setting up and managing projects. For example, Kennedy in her meta-analysis on the effectiveness of PD programs designed to enhance teacher pedagogy in delivering a new program found low effect sizes immediately after PD, but that after follow-up, a year or years beyond the PD year, student achievement was higher at the end of the follow-up year than the end of PD year [30].

Another interpretation for why teachers who had previously received PD on PBL only scored higher on structure-driven PBL practices is that teachers may have to revert to becoming novice teachers, in that they are "learning" and trying out new practices that are more student-centered. It is likely that teachers' attempts at PBL practices will fail along the way towards implementation, resulting in awkward behaviors and shortcomings in orchestrating a successful lesson [41,44]. (Osbourne and colleagues found that teachers in their study who were receiving professional development to enact practices related to project-based learning reported that they had difficulty with behavior management and keeping control and calm when trying to implement project-based learning [39]. This research may suggest that teachers focus more on organizing and managing the project first as a natural course. Once teachers have enough practice enacting projects successfully, they may be able to turn towards adjusting their teaching practices to relate more to purpose-driven goals that can deepen learning.

Another major finding in this study was that teachers who had experienced prior PD in PBL did not have higher purpose-driven PBL practice scores than teachers who had not received prior PD. They were not more likely to support students in engaging in disciplinary inquiry or talk, or to engage students in authentic tasks or iterative processes or choice. To begin, teachers' mean scores for disciplinary inquiry and talk suggest that teachers were providing opportunities for problem-solving which included students talking about possible solutions. In contrast, support of students' iterative processes (i.e., student reflection, revision and peer feedback) was quite low, regardless of condition. As indicated in mean iteration scores, we found that teachers rarely provided opportunities, let alone supported students' iterative processes necessary to higher order thinking processes during problem-solving tasks. Thus, having experienced prior PD did not affect the way teachers interacted with, and supported, students as they grappled with challenging tasks. Previous research has shown that it is quite difficult to see substantial change in teacher interactional processes with, and support of, students even after professional development [39,45,46]. Teachers may be better able to enact straightforward practices, or practices that just require frequency of use, such as stating the lesson objective and connecting it to a curricular goal.

What seems to be most challenging to teachers is on-the-spot enactment of practices within a context that works to guide and scaffold students to stretch understanding levels. This may be because it requires in-depth knowledge of the subject content along with knowledge of ways to help students discover that knowledge [47].

Research regarding teacher support of students have identified questioning, modeling, and scaffolding strategies as integral to deepening students' conceptual knowledge [46,48,49]. Knowledge construction is thought to be dialectic in that it requires comparative thinking, that is evaluating competing alternatives [50]. Classroom conversations and activities in which teachers support the weighing of alternatives help students to reason why something is right, but also why something else may be wrong [39]. Supporting and scaffolding student learning is key in facilitating these higher order thinking processes that lead to deeper learning as teachers become equal partners with their students in the construction of knowledge [49]. When teachers facilitate discussions and activities that model and scaffold comparative thinking strategies to evaluate and justify claims, students begin to adapt and apply these higher-level thinking strategies. Research has shown that students in classrooms with higher-level interactions begin to mirror these interactions with peers to solve problems [51,52].

However, observational research seems to suggest that teacher support mostly entails a focus on factual information and eliciting student ideas rather than in developing student thinking and reasoning [48,53]. Further, Osborne and colleagues found that teachers who had received PD in supporting students during projects were still developing their practices related to facilitating student thinking and reasoning 18 months after the start of the project [39]. Other research has suggested that teachers need at least two years of training to see substantial effects in the quality of support provided to students in the classroom [41,42]. (However, others have noted time spent on PD may not be the biggest factor but, more so, how teachers are engaged with the new content in ways that allow for their transfer of knowledge to practice. We know from prior research teachers improve their practice when PD is contextualized within a community of learning, which allows teachers to exchange their ideas and experiences, and allows teachers to critically reflect [38].

Another reason for teachers' low iteration scores is that teachers may be focusing on overarching goals but have delayed effects on their practices as they make sense of a novel pedagogy. A major goal of project-based learning is to shift responsibility to students for their learning. As such, initially teachers who espouse PBL theory may focus more on getting students to actively engage in learning and rely on their peers, focusing less on themselves as teachers, as in traditional classrooms. As a consequence, teachers may even overlook their importance to successful student-driven inquiry in their attempt to place students at the center of learning. More research is needed on PBL training to explore how programs can balance student-centered learning, on the one hand, and the teacher as integral to that learning process on the other.

Lastly, we were surprised to find that overall, teaching practices related to Authenticity (i.e., supporting students' personal connections and contributions to their world) and supporting student choices during Collaboration were also rarely seen. One of the hallmarks of PBL is that it brings personal meaning and world connections back to student learning. However, we saw very little enactment of teacher practices to support students' personal connection and, consequently, choices in completing authentic tasks, and this may be directly interwoven with the lack of iterative supports involved in higher order thinking processes.

An important aspect of PBL is that it can foster student motivation in that students' perceptions of task value and self-abilities will drive engagement, which ultimately affects student performance [54,55]. When students are given experiential opportunities to do real-world tasks connected to a discipline, students' conceptions of the value of the task, and consequently, the discipline may increase, especially when real-world tasks are shaped in response to students' interests and their own personal experiences driving their exploration [56]. For example, students may come to see the utility in math, science,

or humanities fields when they are engaged in solving problems that impact their lives and surrounding communities. As a result, student engagement in challenging tasks may increase because the students are intrinsically motivated, and, as a reciprocal process, engagement supports students' perceived abilities at completing the task [57]. When students feel they are accomplishing a worthwhile task of their choice and feel confident in their abilities to complete a task, students are more apt to engage and persist in challenging tasks, and thus increase their learning and performance.

Prior research has also indicated that PBL may have positive effects on students' perceptions of task and their abilities [24,54,58]. Yet, in the videos of teacher practice that we collected, we struggled to see support for students' personal connections, choices, and contributions to the world. In thinking over why this may be, we realized that teachers' inclusion and support of personal connections, choices, and contributions to the world may be more apparent in the design of projects, rather than in videos of enactment. Teachers may be designing projects that allow for students to explore their own individual interests, but this may be less apparent in videos of whole-class lessons. It may also be plausible that teachers support students' personal connections, contributions, and choices more so in small groups or in individual conferences. Teachers in our study were more apt to record lessons that were geared towards the whole class, which may be why teachers chose lessons that did not highlight personal connections or real-world contributions or support choices among groups during collaboration. It is also reasonable to speculate that small group and individualized instruction generally are less observed in junior and high school instruction and, as a result, may be indicative of teachers' tendency to neglect responsive supports for students at differing ability and motivational levels within junior and high school. Teachers may need more support to help students explore personal and real-world connections that would help support and inform choices while problem-solving beyond just embedding personal written reflections or activities to choose from in the projects' designs. PD in project-based learning may need to target, specifically, how teachers can foster meaningful conversations surrounding students' connections to disciplinary content that contributes to the world and then, further, target how teachers can support students to reflect in making choices to solve problems. It may be that the more motivational aspects of PBL goals need to be embedded in everyday activities in classrooms.

12. Conclusions

Taken together, this research shows that teachers who had experienced prior PD in PBL increased their structure-driven PBL practices, those practices related to setting up and managing projects. Additionally, teachers who had experienced prior PD in PBL incorporated more student collaboration into their instruction. However, classroom video scores for teachers who had experienced prior PD in PBL did not differ from those who had not experienced prior PD in PBL when it came to *purpose-driven* practices. To see change in teacher processes related to successful enactment of PBL may take a more fine-grained focus on specific practices and include ample time for teachers to rehearse and reflect on their progress.

These findings have led us to hypothesize that teachers may need PD that focuses specifically on the purpose-driven practices of PBL in order to go beyond simply incorporating projects and truly transform their instruction so that it is disciplinarily rich, authentic, iterative, and collaborative. In follow-up studies, we intend to investigate whether targeted PD that focuses specifically on the purpose-driven practices of PBL influences teachers' enactment of these practices in their work with students.

Additionally, future research may want to explore, specifically, differences in the types of engagement teachers undergo to develop new pedagogies during professional development [15]. In other words, teacher learning in professional development may be enhanced when teachers are allowed to share their ideas within a community of learners, have support from professional development coaches, and have time to critically reflect. If teachers are to be able to transfer knowledge to enactment, especially in regard to enacting

a student-centered pedagogy associated with Project-Based Learning, it is essential to uncover which supports of professional development leverage the most change in teacher practices within the classroom.

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