

Graduate Students' Perceptions of the Project-Based Learning (PjBL) Model

A Phenomenological Study in the Context of Puerto Rico

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Abstract

Project-Based Learning (PjBL) model is highly recommended to frame STEM learning experiences to achieve transformative education at all levels. This qualitative phenomenological study describes the perceptions and experiences of graduate students, mostly science teachers, towards the PjBL model implemented in the graduate course they were enrolled during the academic year 2022-2023 at the College of Education of a public university of Puerto Rico. The study involved 12 graduate students, 6 master's and 6 doctoral students, who took one of the core courses of their program in Curriculum and Teaching with a subspecialty in Science Education. The findings indicate that the PjBL model was perceived as a constructivist learning model that allowed greater learning of the course content. Motivation and collaborative learning are two elements that stand out as essential to their learning process.

Keywords: Project-based learning; Graduate students; Science curriculum

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Introduction

A new vision for science education is presented in the document *A Framework for Science Education: Practices, Cross-Cutting Concepts, and Disciplinary Core Ideas* (NRC, 2012). The idea is that students will learn about science by doing engineering and science activities that help them understand natural phenomena and solve problems. The Next Generation Science Standards (NGSS, 2013) guide science teachers, science teacher educators, researchers, and leaders to achieve the goals stated in the *Framework* for all students. Among the many initiatives to advance science education reform, one that stands out is the design and implementation of curriculum units with the Project-Based Learning model (PjBL) (Bender, 2017; Larmer et al., 2015). In fact, the PjBL model has been highly recommended to frame STEM learning experiences to transform science education (Carpraro et al., 2013; Edmunds et al., 2017; Jiang et al., 2024; Surmani et al., 2023). But even when extensive research suggests the effectiveness and promises of PjBL, many science teachers still feel challenged to design and implement PjBL curriculum units (Condliffe et al., 2017; Kurt & Akoglu, 2023; Tamim & Grant, 2013). One way to attend these challenges is to provide pre-service and in-service science teachers with constructivist learning experiences framed in problem or project-based learning principles. Precisely, the purpose of this study is to analyze the experience and perceptions of graduate students with the PjBL model and how it enhances their learning of the course content, that includes the model itself.

This paper is guided by the following research questions: 1) What are the graduate students' perceptions of the Project-Based Learning Model as part of their experience with a curriculum unit designed with this model in a required Science Education graduate course? and 2) How does the PjBL model facilitate the learning of the content of the course in which it was implemented? Some of the graduate students are active in-service science teachers at the middle or high school level, while others are not. One of the most interesting things about this study is that it looks at both, their experiences as graduate students learning about the PjBL model as part of their course work and, as science teachers designing a curriculum unit using a constructivist instructional model, including PjBL, in Puerto Rico, where research studies on this topic are scarce.

Overview of the Project-Based Learning Model (PjBL) and its implementation in different contexts

Project and problem-based learning are terms that have been used interchangeably in the literature up until the early 2010s, thus creating some confusion regarding the differences between these approaches (Condliffe et al., 2017; Thomas, 2000). Generally speaking, problem/project learning

environments are characterized as student-centered or constructivist pedagogies; use real-world problems to engage students in inquiry; involve collaborative or cooperative learning structures; teachers assume the role as facilitators; are used for interdisciplinary curriculum design; among other characteristics (Bender, 2012; Blumenfeld et al., 1991; Condliffe et al., 2017). Some key differences between problem-based learning (PBL) and project-based learning (PjBL) are: 1. PBL is problem-driven, while PjBL is project-driven (Dole et al., 2016), 2. PBL can be seen as a teaching and learning strategy inserted into the PjBL model (Barron et al., 1998; Krajcik & Czerniak, 2007; Mitchell & Tilley, 2024), 3. PBL implementation time is usually less than the required time for PjBL implementation (Dole et al., 2016; Mitchell & Tilley, 2024) and 4. PjBL, can be used to: design a semester course or curriculum units (Baumgartner & Zabin, 2008; Svihla & Reeve, 2016; Vázquez-Alvarado, 2020); can be used as primary pedagogy to deliver the curriculum in some schools, for example, the New Tech Network schools (Culclasure et al., 2019; Lee et al., 2019) or even used to design undergraduate programs (Mitchell & Tilley, 2024).

Even when there have been different approaches or meanings to what PjBL means (Condliffe et al., 2017; Larmer et al., 2015; Thomas, 2000), there is consensus among researchers (Bender, 2012; Blumenfeld et al., 1991; Krajcik & Czerniak, 2007) on key elements that define PjBL. These are: a) a driving question based on a real-world problem, b) sustained inquiry, and c) the creation of final products that are central to the curriculum.

At the K-12 level, the design and implementation of the PjBL curriculum units are more evident and frequent, as many studies suggest (Condliffe et al., 2017; Craig & Marshall, 2019; Culclasure et al., 2019; Krajcik & Czerniak, 2007; Kurt & Akoglu, 2023). But literature suggests that the implementation of project-based learning is less prominent at the undergraduate level and even more scarce at the graduate level (Lee et al., 2014; Surmani et al., 2023). Some studies at the graduate level with PjBL are focused on teacher education programs such as the one conducted by Major & Mulvihill (2019) in Botswana; Surmani et al. (2023) in Indonesia, and Lee et al. (2014) with different undergraduate and graduate programs, including the College of Education, from the University of Indianapolis at Indiana, USA. Other studies at the graduate level focus on the use of the PjBL model to design online courses to determine how the experience enabled students to learn the content and develop 21st-century skills (problem-solving, collaboration, critical thinking, among others) in these online courses (Dabbagh & Williams, 2010; Wu et al., 2023). Our PjBL study in Puerto Rico is an attempt to enrich the PjBL research literature at the graduate level. In the next section, we discuss more details of the initiatives toward integrating the PjBL model at different levels in the context of Puerto Rico.

Research gaps on Project-Based Learning in Puerto Rico

The adoption of Problem (PBL) and Project-Based Learning (PjBL) methodologies in Puerto Rico has been a growing interest in science education (Velázquez & Figarella, 2018). However, research on the design and implementation of PjBL curricula remains scarce compared to international contexts. Despite various efforts to promote active learning strategies, formal research on their application across different educational levels in Puerto Rico is still limited and fragmented.

Since the 1990s, Puerto Rico has attempted to modernize science education by implementing student-centered methodologies, such as Project-Based Learning (PjBL). However, these initiatives have often been short-lived due to shifts in the Puerto Rico Department of Education (PRDE) leadership, budget constraints, and a lack of continuity in teacher training (Díaz Díaz, 2021; Vázquez & Figarella, 2018). A big problem that has kept PjBL from being effectively and permanently integrated into science curriculums at all levels is that teachers haven't had access to structured and ongoing professional development (Rivera González, 2022). The PRDE's 2016 Science Program Circular recognized the importance of active learning strategies like PjBL. However, large-scale implementation has faced persistent challenges, including inadequate teacher training and resistance to moving away from traditional, memorization-based instruction (PRDE, 2022). Teachers often lack sufficient preparation and institutional support to confidently design and execute PjBL units, leading to inconsistent adoption across schools. As a result, many science educators continue relying on conventional lecture-based approaches, despite growing evidence that PjBL enhances student engagement, problem-solving skills, and scientific literacy (Díaz Díaz, 2021).

Despite these challenges, some studies have highlighted successful attempts to implement PjBL in Puerto Rico. For instance, Vázquez-Alvarado (2020) examined how PjBL, combined with digital tools like Minecraft Education, significantly improved student engagement in science learning. However, he also pointed out that without clear guidelines, sufficient teacher training, and institutional backing, the large-scale adoption of PjBL remains difficult.

At the university level, Rivera González (2022) explored PjBL through Service-Based Learning (SBL) in an analytical chemistry course. The author noted that at this level, PjBL remains underutilized, with few structured frameworks guiding its application in STEM disciplines. This limited adoption is largely attributed to insufficient teacher training, which affects both the confidence and capacity of educators to integrate PjBL effectively into their curricula. Consequently, teacher preparation has emerged as one of the biggest obstacles to the widespread implementation of PjBL in Puerto Rico.

Similarly, Díaz Díaz, (2021) indicate that science teachers struggle with implementing PjBL due to insufficient training and a lack of resources in public schools. This author examined its use in middle school science, noting increased student motivation and critical thinking, particularly in renewable energy and sustainability projects.

Despite individual successes, PjBL efforts in Puerto Rico remain isolated to specific schools and universities, such as the laboratory schools (K-6th and 7th-12th grade) of the University of Puerto Rico (Velázquez & Figarella, 2018). There is no comprehensive database systematically documenting its effectiveness across different educational levels, limiting efforts to expand these methodologies nationwide. The lack of longitudinal studies further prevents the development of educational policies that support sustained PjBL implementation. Additionally, the traditional focus of teacher education programs in Puerto Rico provides little exposure to active methodologies like PjBL (Rivera González, 2022).

One way to increase science teacher's confidence and knowledge in implementing PjBL curriculum units is to have them experience the model as students themselves. As Major & Mulvihill (2018) state, "If PjBL is the desired approach, then it ought to be demonstrated in regular use in teacher education programs" (p. 2). Thus, the purpose of this study is to examine graduate students' perceptions of the PjBL model as part of their required courses in the Science Education Graduate Programs at one campus of the University of Puerto Rico (public university).

Many schools and researchers (Craig & Marshall, 2019; Culclasure et al., 2019; Virtue et al., 2019) now use the Gold Standard PBL framework to define and think about project-based learning. This framework was developed by the Buck Institute of Education (BIE), which has more than 30 years of experience as a leading PBL implementation organization. Thus, it is used to frame our study.

Gold standard PBL: Theoretical framework

The Gold Standard PBL framework (www.pblworks.org) includes three essential aspects: 1) the learning goals at the center, 2) the seven essential design elements, and 3) the teaching practices required to support the implementation process. The following diagrams describe the seven key design elements and teaching practices required for the successful implementation of PjBL according to BIE. For a PjBL project to be rigorous and meet the Gold Standard PBL framework, it must comply with seven key elements as illustrated in the right diagram below. These elements are 1. a challenging problem or question, 2.

sustained inquiry, 3. authenticity, 4. student voice and choice, 5. reflection, 6. critique and revision, and 7. a public product (www.pblworks.org). These are what Larmer et al. (2015) describe as the key design elements to take into account when designing PjBL curriculum units. These authors highlight at the center of the project the learning goals, which include both the discipline or subject matter standards and what they call success skills, which are also denominated as 21st-century skills, which involve the 4Cs (communication, collaboration, creativity, and critical thinking) among others. A few years later, Boss & Larmer (2018) detailed the seven teaching practices required to sustain rigorous and successful PjBL projects. The left diagram below details these practices. First, the project must be aligned to standards, and the following teaching practices are needed: 1. Build the culture, 2. manage activities, 3. scaffold student learning, 4. engage and coach students, 5. design and plan, and 6. assess the student learning outcomes (Boss & Larmer, 2018).

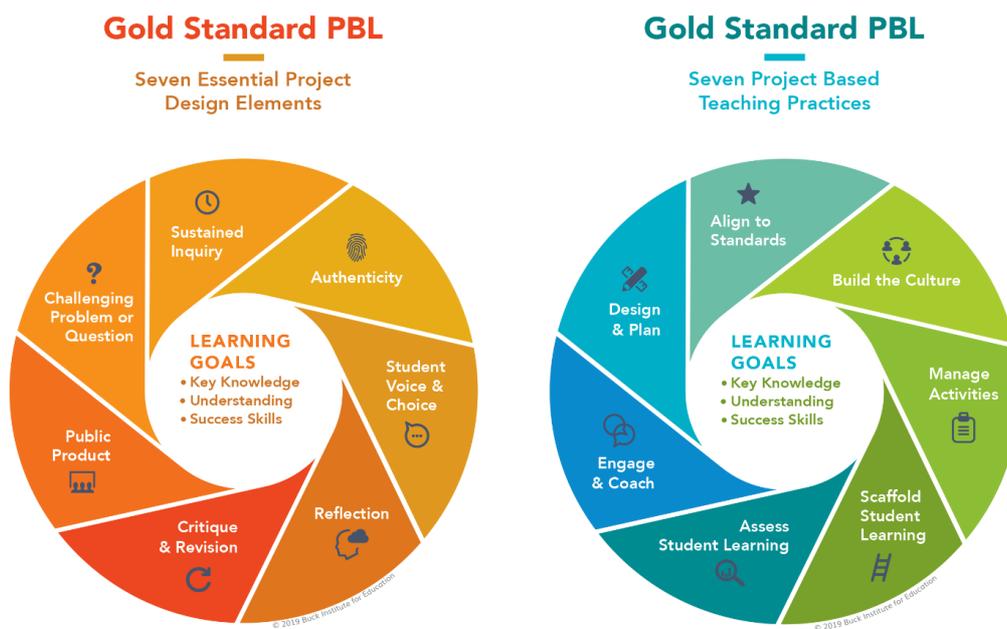


Figure 1. The key elements of the Gold Standard PBL.

Note: This figure represents the key elements of the Gold Standard PBL: Design Elements (figure at the right) and Seven Project Teaching Practices (figure at the left) that support the design and implementation of project-based learning curriculum units. From <https://www.pblworks.org/what-is-pbl/gold-standard-project-design>

Context of the study

The study was conducted in the Graduate Program (Master and Doctorate) of the College of Education of the University of Puerto Rico (UPR). The two

required courses for the Master's and Doctorate Programs were offered during the academic year 2022-2023 in which the designed PjBL curriculum unit were implemented. Course A (Master) and Course B (Doctorate) are required courses of the Curriculum and Teaching with a subspecialty in Science Education Program. Course A was offered in the first semester and Course B in the second semester of 2022-2023 academic year. Both courses include the topic of theories and instructional methodologies for science education at the secondary level (high school) as part of their course syllabus. These constructivist instructional methodologies include problem-based learning (PBL), project-based learning (PjBL), the 5E inquiry model (Bybee et al., 2006), and cooperative learning, among others. Despite slight differences in the syllabus of the courses, both share similar content.

A key design element of the Gold Standard PBL Framework is authenticity and that the project must respond to a real-world problem or call to action. In this particular case, a memorandum of understanding (MOU) was signed between Corazon Latino, a non-profit organization that had the task of developing lesson plans to attend to four major themes selected by the communities near El Yunque and the Graduate Program of the College of Education. These themes were: 1. Biodiversity of El Yunque, 2. Climate Change, 3. Soils, and 4. Connectivity. In the MOU, graduate students of the UPR would collaborate on the design and development of curriculum units that addressed Corazon Latino's curriculum project.

This unique opportunity provided the setting to incorporate this project into both courses and design a PjBL curriculum unit that would combine the needs of the organization and the learning goals of each course content, creating a real-world context for the project. For the design of the PjBL unit, the resources available at pblworks.org were used to design the curricular unit for both courses. These resources are of free access and available to modify by any user. In this case, the resources used (Planning Tool template and Project Wall template) were translated to Spanish by the lead author.

Research design

The study is guided by the following research questions:

- 1) What are the graduate students' perceptions of the Project-Based Learning (PjBL) model as part of their experience with a curriculum unit designed with this model in a required Science Education graduate course?
- 2) How does the PjBL model facilitate the learning of the content of the course in which it was implemented?

A qualitative study with a phenomenological design was selected among the different qualitative study designs (case study, action research, ethnography, among others), because the first research question is aimed at understanding the perceptions and experiences of the participants of the study (Creswell, 2012). According to Merriam & Tisdell (2016), phenomenology is a qualitative research design that focuses on the lived experience of the participants, which is the principal focus of this study, understanding the lived experience of participants with the PjBL model. Also, a phenomenological design helps us to better understand their perceptions about the Project-Based Learning (PjBL) model that framed the design and implementation of one curriculum unit in one of the courses in which they were enrolled. The study protocol was submitted and approved by the Institutional Review Board (IRB protocol #2223-016).

To ensure a rigorous study and obtain reliable results, it is essential to use a variety of data collection techniques. In this research, the following data collection techniques were used: 1. semi-structured interviews (two interviews per participant—initial and final), 2. non-participatory observations (2 conducted during the implementation of the PjBL unit), 3. document analysis (reflective notebooks and final products), and 4. one focus group two months after the completion of Course A. The focus group after the completion of Course B was not conducted due to scheduling difficulties with participants. All these data sources were used to triangulate the results as a strategy to ensure reliability. In terms of the protocols (semi-structured interviews, observation and focus group) used to gather data, all were aligned to the Gold Standard PBL framework key design elements as a way to have validity of construct.

All graduate students (15- 6 for Course A and 8 for Course B) enrolled in both courses were invited to participate in the study. Even when all students signed the consent forms, only data from 12 participants who completed the first and final interviews was considered in the data analysis. The final products of the PjBL curriculum unit for each course consisted of a high school science curriculum unit designed in collaborative groups in which they had to apply the content and skills learned in the course. Therefore, even when not all students were able to become full participants in the study, all curriculum units or final products were part of the data analysis because they were elaborated collaboratively. Table 1 shows important demographic information about the participants of the study.

Course	Participants	Gender	General Background Formation of Participants
A Master Program	6 3 in service teachers 3 not active in-service teachers	3- men	4- Bachelor degree in Natural Sciences (Biology or Chemistry) 2- Bachelor degree in Elementary Education (4-6th grade)
		3- women	
B Doctorate Program	6 3 in service teachers 3 not active in-service teachers	4- men	4 Bachelor degree in Natural Sciences (Physics and Biology) 2 Bachelor degree in Education
		2- women	
Total: 12 participants 5 women 7 men			

Table 1. Demographic information of participants of the study.

Note: Table 1 illustrates important demographic information of the participants of the study.

Data Analysis

The process of data analysis included both deductive and inductive coding cycles as recommended by Saldaña (2021). The analytical process incorporated multiple strategies to ensure depth and consistency. First, the Gold Standard PBL seven design elements were employed as a framework for deductive coding analysis of both the initial and final interview transcripts for both courses (see Appendices A and B). This approach facilitated a comparative analysis to determine learning growth in participants' understanding of the Project-Based Learning model. Then, an inductive *In Vivo* coding technique (Saldaña, 2021) was implemented for both sets of interviews to determine the categories and themes that emerged from the data. Other sources of data, document analysis (reflective notebooks and final products), focus group transcripts, and non-participant observations were used for data triangulation purposes, which is considered an important reliability data analysis technique. Also, the deductive and inductive coding cycles described above were conducted independently by each researcher to compare data analysis and ensure reliability of results. Peer debriefing meetings among researchers was conducted on several occasions to share insights and results of the coding cycles. Finally, an analysis assisted by artificial intelligence, Anthropic AI's Claude.ai tool was used, applying the CORIF strategy (Context, Objective, Role,

Information, and Format) proposed by Etesse (2024), to optimize AI (Artificial Intelligence) training, which resulted in more relevant and precise analyses. The AI tool was used after conducting independent data analysis and it served only to verify the findings that the researchers have already concluded. Having a strong theoretical framework (Gold Standard PBL) to guide the data analysis and using the qualitative data analysis techniques described above, alongside the AI Claude tool, helped researchers in ensuring reliability of the findings that are presented in the next section.

Potential biases and how they were addressed

The lead author is both the principal investigator and the professor of the graduate courses in which the study was conducted. We recognize that the dual role could create potential biases. To address this potential bias, the data was collected by the first author but was not analysed until each course finished, thus separating the role of researcher and professor. This precaution was part of the IRB protocol.

Findings

This study examined the perceptions of graduate students of a Science Education Program regarding the Project-Based Learning (PjBL) model implemented in a graduate course as well as how the model facilitated the learning of the content of the course. The findings are presented to answer each research question. To describe the perceptions of graduate students and their experience with the PjBL model, the analysis of the initial interview transcripts shows that participants from both courses had limited knowledge or understanding of the PjBL model before its implementation in each course. None of them had previous experience with the model as students themselves (K-12), but all had positive attitudes towards PjBL in regard to wanting to learn more. Nonetheless, they perceived some challenges towards the implementation of PjBL, such as time constraints, lack of training, and uncertainty on how to implement it in their school contexts. Only two participants from course A had previous experience with PjBL at the undergraduate level, and both were formed as elementary science teachers. Two participants from Course B had implemented PjBL, or what they believed it was, with their students as in-service science teachers. For example, one participant from Course B stated, "When this came to Puerto Rico, they (PRDE) gave us some workshops at the school, but they were very superficial. They didn't exactly explain how to implement it."

When comparing the design elements of the Gold Standard PBL framework from initial and final interviews through deductive coding, the data shows that

participants were able to identify five or more design elements after going through the experience of a PjBL unit in their course. Before launching the project, the two design elements identified by participants were the final product and sustained inquiry. Also, only one participant highlighted the design element of reflection from the PjBL experience, which is interesting due to the fact that a reflection journal was part of the unit. Figure 2 illustrates a bubble diagram that highlights the similarities and differences among the participants from both courses.

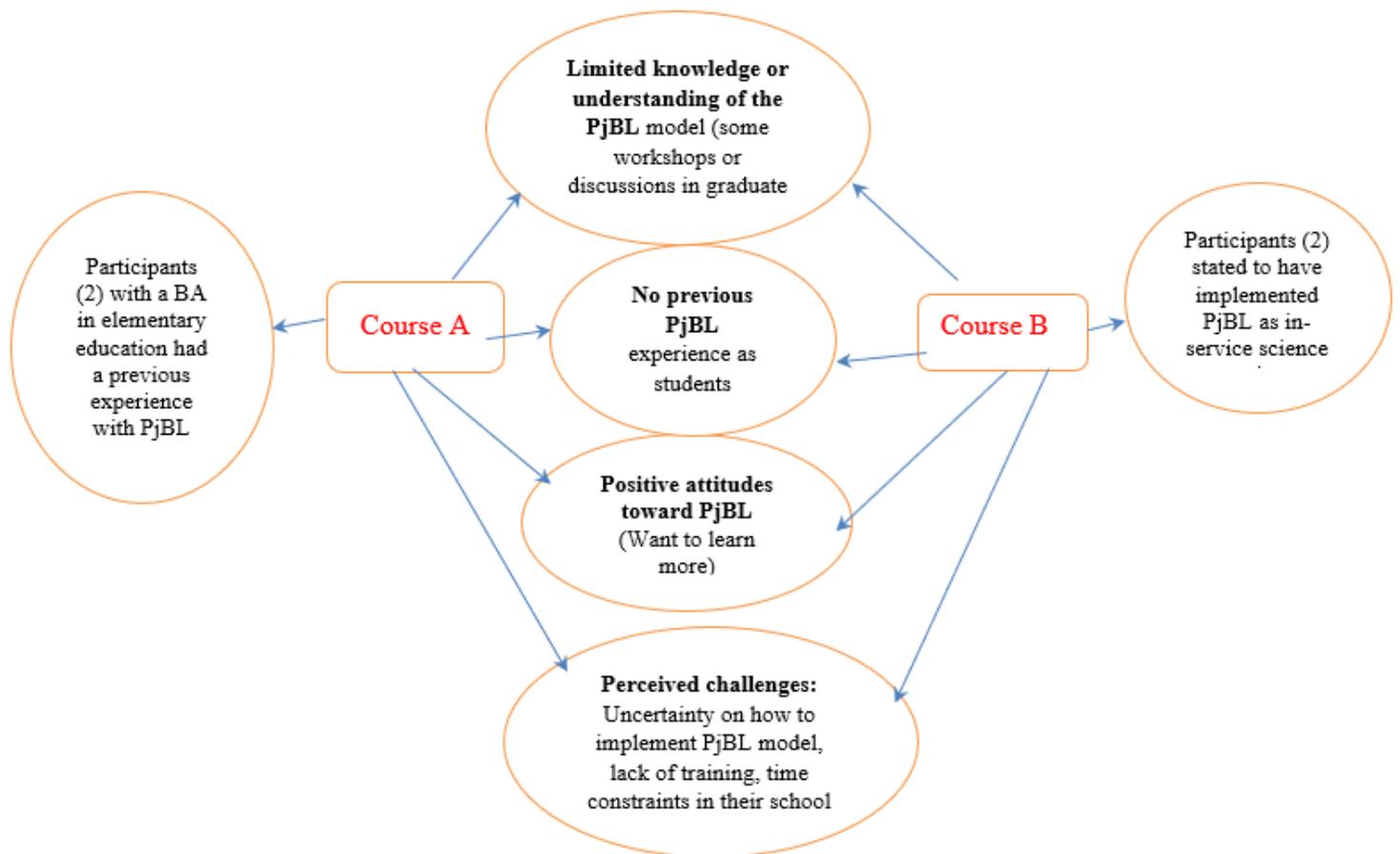


Figure 2. Comparison of initial interviews from the two graduate courses (Bubble Map).

Note: This figure was created by Delgado-Quiñones (lead author) to compare findings from the initial interviews between Course A and B. The bubbles in the middle represent the similarities, while the bubbles at the left of each rectangle represent the differences found between the participants from each Course.

In terms of the lived experience, our findings indicate a predominantly positive experience, highlighting collaborative dynamics, active learning, acquisition of

21st-century skills, and connection to real world contexts as valued aspects. When asked to describe their experience in the course, participants stated, "Unique experience," "I loved it," "It was challenging," and "Good balance in the collaborative work." To summarize, one participant from course B stated, "I loved it because everything was really dynamic; at no point was anything boring; it was quite entertaining and motivating."

This overall positive perception suggests that the PjBL model successfully captured students' interest and engagement, a crucial element for the success of any pedagogical approach. Regarding the learning of the PjBL model itself, variations were observed in understanding specific implementation stages of the PjBL model, suggesting the need for explicit reinforcement of its structure and design elements. Nevertheless, participants reported greater confidence in implementing the model in their own classes after the experience. For example, one participant from course B stated, "I feel quite confident," when asked about their ability to implement the model. In fact, participants of the focus group from course A affirm that they were already implementing PjBL with their students during the second semester. They stated that students were really engaged, but the biggest challenge was in the phase of creating the final products. This is similar to the challenges they faced themselves as part of the PjBL course experience, which include the development of the final product, coordinating the collaborative work, effective communication, and content contextualization. Mostly, they enjoyed the dynamic and collaborative activities in class, the feedback given by peers and experts, and field experiences, which included a guided visit to El Yunque National Forest, this was evident in the reflective notebooks, non-participant observations and individual interviews.

To answer the second research question, the implementation of the PjBL curriculum unit in each course served to promote learning course content. Multiple data sources (final interviews, document analysis, and non-participant observations) showed that participants' learning of different teaching strategies and models was significant. They were able to explain and compare different teaching and learning strategies for science education, which provides evidence of their understanding of different pedagogical approaches facilitated by the PjBL model. For example, one participant (in-service science teacher) from Course B stated, "I think the most important thing I learned is to maybe not compromise oneself with only one model," while another participant from Course A stated, "My greatest learning gain in this experience was learning the model itself, because I did not understand it." Table 2 summarizes the final products (projects—curriculum units designed) for each graduate course. The final products were part of the data analysis of the study and were used to triangulate the findings with other data sources. Each collaborative group would choose the theme provided by Corazon Latino for the curriculum design.

The design is guided by the theoretical principles of the instructional methodology used (5E Inquiry Model, PBL, PjBL or other). An important guideline provided to students for the development of the final product is that the curriculum unit designed had to be aligned to PRDE Science Curriculum Standards.

Course A	Theme and instructional methodology used to design the curriculum unit - final product	Course B	Theme and instructional methodology used to design the curriculum unit - final product
Group 1	<u>Climate Change</u> Project Based Learning 12 th grade Environmental Science	Group 1	<u>The effects of climate change</u> Problem based learning 12th grade Environmental Science
Group 2	<u>Biodiversity of el Yunque</u> 12th grade Environmental Science PROCIC Model (López-Tosado, 1997)	Group 2	<u>Connectivity: From the mountains to the coastal area</u> 12th grade Environmental Science Learning cycle - ECA Exploration, Conceptualization and Application (Villarini-Jusino, 1991)
Group 3	<u>Soil</u> Project Based Learning 9th grade Earth Science	Group 3	<u>Biodiversity of moses at El Yunque and the impact of climate change</u> 12th grade Environmental Science PROCIC Model (López-Tosado, 1996)
2 curriculum units designed with PjBL, 2 with PROCIC Model, 1 with PBL and 1 with ECA Learning cycle strategy. PROCIC and ECA were developed by Puerto Rican authors.			

Table 2. Final product description for each graduate course.

Note: Table 2 summarizes the topic and the constructivist learning model or strategy that guided its design. This content is part of the Syllabus of each Course. The final products were part of the data analysis of the study.

An interesting finding from the analysis of the final products is that students integrated into their lesson plans, cooperative learning techniques they experienced themselves through the implementation of the PjBL curriculum unit. For example, two curriculum units from Course A, groups 1 and 2, integrated the Fishbowl Protocol used in the course into their final product. In

the case of the final products of Course B, groups 1 and 2 integrated the Tuning Protocol that was implemented as part of the PjBL unit. Figure 3 illustrates a bubble diagram that compares their learnings and perceptions of PjBL experience in the course. The diagram allows us to answer both research questions as well.

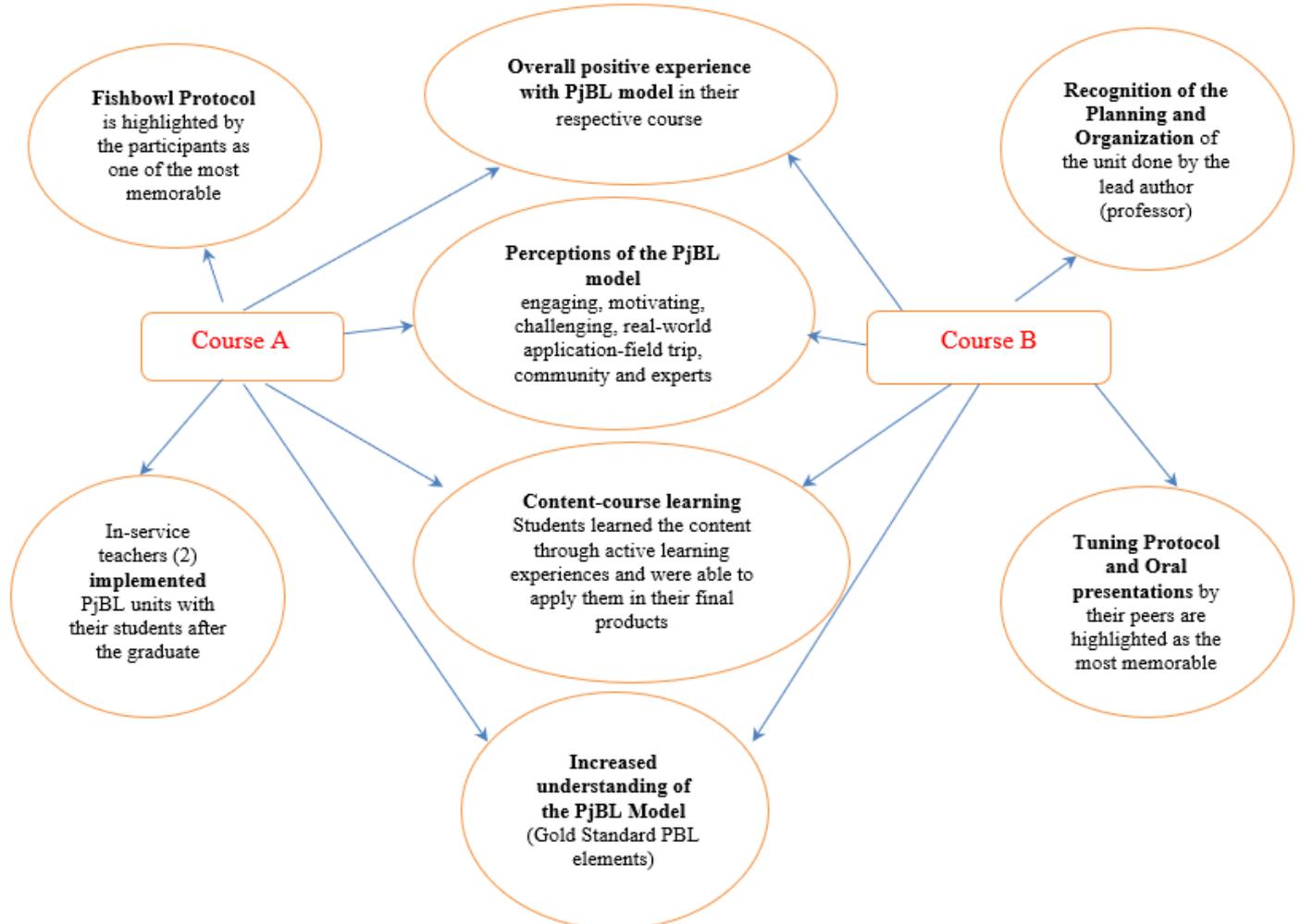


Figure 3. Comparison of overall findings among Course A and B.

Note: This figure was created by Delgado-Quiñones (lead author) to compare the overall findings of the study between Course A and B. The bubbles in the middle represent the similarities, while the bubbles at the left of each rectangle represent the differences found in each Course.

The results of this study highlight the promise of the Project-Based Learning Model (PjBL) for multiple purposes: learning the course content and other skills; learning about the model itself; preparing in-service science teachers on how implementation of PjBL looks and feels like, among others. Also, it addresses a research gap in the context of Puerto Rico, a US territory, in which

resources for teacher professional development are limited to one-day workshops mostly. Also, curriculum materials for PjBL design and implementation are limited due to several factors, the language barrier (Spanish) being one of the most cited among in-service science teachers. In the next section, we discuss the implications for practices of the findings of the study.

Discussion of findings

There are many challenges teachers face when deciding to use PjBL to design and implement their curriculum. Lack of time, state-mandated assessment tests, lack of support from principals, science teachers' beliefs about the PjBL model, or having few professional development opportunities represent some of the cited challenges in the research literature (Condliffe et al., 2017; Culclasure et al., 2019; Edmunds et al., 2017; Kurt & Akoglu, 2023; Tamin & Grant, 2013). In the United States of America (USA), the resources and efforts to promote PjBL are widely recognized (Chen et al., 2024; Condliffe et al., 2017; Culclasure et al., 2019; Lee et al., 2014; Virtue & Hinnant-Crawford, 2019). But the geopolitical and cultural context does play a role in how reforms are carried out because it exerts influence on the teaching practices in any society, as reflected in the study on problem-based pedagogies in teacher education programs in Botswana conducted by Major & Muvihill (2018). In the context of Puerto Rico, PjBL is part of the public policy (PRDE, 2022) and is highly recommended, but very few pre-service or in-service teachers have experienced PjBL in their K-12 school years, as was evidenced in our study.

Puerto Rico's geopolitical context is unique in that it is characterized by its territory status to the USA, which means that our educational system emulates that of the USA, but the implementation of educational reforms does not necessarily follow the same path or timeline as in the USA. One way to attend to these challenges is to have a clear understanding of the PjBL model; and the "Gold Standard PBL" framework provides the resources to accomplish this. Nonetheless, many of these resources are in English, and very few are available in Spanish, which is the native tongue language in Puerto Rico.

In some schools in USA, like the schools that are part of the New Tech Network Design (NTN), they use the "Gold Standard PBL Framework" (Culclasure et al., 2019; Virtue et al., 2019) to guide the professional development of their teachers and principals, design the school curriculum across different disciplines, and create a problem/project-based learning environment. Having a clear understanding of the design elements and teaching practices to support student learning and development of skills results in positive opinions and perceptions

among teachers and students (Culclasure et al., 2019). For example, in the study conducted by these researchers, many teachers agreed that PjBL made them more effective teachers. Results from this study indicated that teachers believed that the PjBL model improves student achievement, participation, and the application of information more than any other instructional model (Culclasure et al., 2019). Also, teachers reported that having a clear vision for PjBL in their schools supports the process of implementation. Similar to these findings, our results suggest that using the "Gold Standard PBL" framework provided a clear guide for the design and implementation of the curriculum unit, as well as guiding the learning process of the PjBL for the graduate students of both Course A and B. This led to the overall positive perceptions of the PjBL model.

The cooperative and collaborative structure is not considered as one of the key design elements of the Gold Standard PBL framework, but our findings reflect that this collaborative structure of the PjBL unit was key for their positive experience and learning, even when the cognitive demand of the final products was challenging. Boss & Larmer (2018) state as one key teaching practice, managing activities and some of these activities occur in cooperative or collaborative groups. Even when the collaborative and cooperative structure is included in the types of activities the teacher must manage, it is not considered a key design element of the framework. We suggest that this element should be included in the Gold Standard PBL framework to make teachers and students aware of the importance of collaboration and cooperation in the learning process.

The findings presented in this study suggest that implementing the PjBL model at the graduate level promotes student learning of course content and is perceived as a constructivist learning model by the participants of the study. Understanding how to design and implement PjBL curriculum units is a key component to increase the pedagogical content knowledge (PCK) of in-service science teachers and their self-confidence with constructivist learning models, such as PjBL. Particularly at teacher education programs, teacher educators and researchers must not only talk or lecture about problem- and project-based learning models; they should apply them to their courses and serve as role models of constructivist learning environments. One cannot assume that science teachers will design and implement PjBL based on reading about it; experiential experiences, such as the one described in this paper, are necessary to increase their self-confidence and understanding of the key design elements and teaching practices aligned to the "Gold Standard PBL Framework." It is precisely the use of this theoretical framework in the design of the curriculum unit implemented in both courses, that also served to guide the study is one aspect to take into consideration when conducting future studies. Our findings suggest that a clear understanding of the PjBL model and its underlining

principles is key for its correct implementation at all levels or contexts. Using the “Gold Standard PBL” framework provides a starting point for teachers, teacher educators and researchers to create more constructivist learning environments for their students. Using this framework can guide future research to better understand the educational context in which PjBL is being implemented.

Limitations of the study

We recognize that the results are limited to the context of the study and may not transfer or apply to other contexts or participants. Also, classroom observations were limited due to scheduling conflicts with other collaborating colleagues.

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Appendix A

Gold Standard PBL Framework: Design Elements

Initial Interviews (October 2022): Deductive Coding – Course A

Participant Number →	#1	#2	#3	#4	#5	#6
Key Design Elements ↓	Bachelor degree in Education	Bachelor degree in Biology	Bachelor degree in Education	Bachelor degree in Biology	Bachelor degree in Biology	Bachelor degree in Biology
Challenging problem or driving question	√	√	√	√		√
Sustained inquiry			√			
Authenticity		√	√			
Student voice and choice	√		√	√		√ student centered
Reflection						
Critique and Revision						
Public Product	√	√	√	√	√	√
**Collaborative work Additional element that emerged				√	√	√ Social learning

Participants describe PjBL as a learning model.

Appendix B

Gold Standard PBL Framework: Design Elements

Final Interviews (December 2022): Deductive Coding – Course A

Participant Number →	#1	#2	#3	#4	#5	#6
Key Design Elements ↓	Bachelor degree in Education	Bachelor degree in Biology	Bachelor degree in Education	Bachelor degree in Biology	Bachelor degree in Biology	Bachelor degree in Biology
Challenging problem or driving question	√	√	√	√	√	√
Sustained inquiry	√	√	√			√
Authenticity	√		√ Context			√
Student voice and choice	√	√	√ The role was different from previous experience	√	√	√
Reflection		√				
Critique and Revision	√ Tuning Protocol Greatest learning experience	√		√ Tuning Protocol Greatest learning experience	√	√ Tuning Protocol Greatest learning experience

EARLY VIEW
Graduate Student's Perceptions of the Project Based Learning (PjBL) Model

Public Product	√	√ Greatest learning experience	√	√	√	√
**Cooperative and collaborative learning	√	√ It was a challenge but was able to manage it	√	√	√ Highlights this element	√ Fishbowl Protocol

- The theme of motivation emerged among the participants as they stated that by working the course with this PjBL model, they felt motivated all the time to attend the classes.
- They also state that many of the activities carried out in class were integrated into their curricular units. This could be evidenced in the curricular units (e.g., Climate Change).
- In the final interviews, the participants expressed that after this experience they feel more confident in implementing the Project-Based Learning model. They also see it as an interdisciplinary model in which various subjects can be integrated.