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Novice secondary teachers' developing beliefs on implementing project-based learning

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Abstract

The purpose of this study was to identify novice teachers' beliefs about their implementation of and instruction with project-based learning (PjBL) in authentic secondary science and mathematics classrooms in their first school placements as teachers of record. PjBL as an inductive instructional method with a specific focus on active learning. Teachers' beliefs are one of the key determinants in their decision-making for using teaching practices and how to teach. Investigating beliefs contributes to the knowledge base related to the progressive development of PjBL in K-12 classrooms. Despite this focus, little is known about novice secondary teachers' beliefs on implementing PjBL. Utilizing a qualitative approach, data from two focus group interviews revealed two themes capturing participants' developing beliefs about project-based instruction: (a) beliefs about how students learn with PjBL implementation and (b) beliefs about instruction with PjBL implementation. Implications include the need to conceptualize a complex perspective of PjBL from school and classroom contexts, and to move away from conceptualizing PjBL as a set of procedures that conform to classroom practices.

Keywords: beliefs, project-based learning, secondary novice mathematics teachers, secondary science teachers

INTRODUCTION

The study reported here investigated novice secondary mathematics and science teachers' developing beliefs about project-based learning (PjBL). The study specifically aimed to identify novice secondary mathematics and science teachers' developing beliefs from actualized PjBL instruction, that is, the implementation and enactment of PjBL curriculum in authentic 9-12 grade mathematics and science classrooms. Literature (Farrow et al., 2022; Grossman et al., 2019; Miller et al., 2021; Saavedra et al., 2022) claims that PjBL as an inductive instructional method with a specific focus on active learning and problem-based learning (PBL) aligns with the student learning goals expressed in current policy documents in science education (next generation science standards [NGSS]) (NGSS Lead States, 2013) and mathematics education (National Council of Teachers of Mathematics [NCTM], 2014). PjBL is characterized by student learning outcome that includes students' construction of a final product to an extent that demonstrates and measures their understanding of the subject or subject areas underpinning the final product. In this study we use the aforementioned construct of PjBL to distinguish PjBL from the construct of PBL that is often incorrectly and interchangeably used to describe PjBL. PBL, in contrast, involves students solving and constructing solutions to a specific, real-world problem within a shorter timeframe and underpinned by a single subject area.

Background

Most importantly, recent research states that PjBL as an instructional method promotes and supports equitable classroom learning outcomes for underserved students by broadening their engagement and learning

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Contribution to the literature

- Previous research has shown that classroom instruction with Project-Based Learning is complex.
- The study finds that framing Project-Based Learning as a set of procedures hinders classroom implementation and that teacher beliefs impact authentic classroom implementation of Project-Based Learning.
- The present study suggests that Project-Based Learning needs to be conceptualized in light of teacher beliefs.

in classrooms through localized and relevant place-based problems and/or questions requiring students to collaboratively apply their community experiences and assets and their disciplinary ideas to construct authentic artifacts or solutions (Al-Balushi & Al-Aamri, 2014; Hsu et al., 2015; Miller et al., 2021). Through its inductive, active, and equity-based focus on problem-solving, PjBL has been identified in the literature as an instructional method that promotes positive student learning outcomes, specifically: academic achievement gains in mathematics and science (Condliffe et al., 2017), problem-solving skills and self-confidence (Al-Balushi & Al-Aamri, 2014), engagement, participation, and access to learning disciplinary core ideas through the application of the ideas in designing authentic artifacts or multiple solutions (Farrow et al., 2022; Hsu et al., 2015; Wilson, 2021).

PjBL Impact on Students

Currently, PjBL has grown in popularity as an alternative to traditional instruction (Oguz-Unver & Arabacioglu, 2014) with its focus on a student-centered setting (Kokotsaki et al., 2016) and with projects functioning as the core of the curriculum. It should be noted that PjBL has often been used in the sciences (Rogers et al., 2011) and in mathematics (Han et al., 2015; Holmes & Hawang, 2016). Importantly, PjBL has been shown to increase student motivation (Krajcik & Czerniak, 2014) as well as student interest in content (Holm, 2011) and engagement in learning (Almulla, 2020). As such, attitudes toward learning and content have been shown to improve with the use of PjBL (Bender, 2012; Tseng et al., 2013) along with increases in academic achievement (Chen & Yang, 2019) and in metacognition (English & Kitsantas, 2013; Thomas, 2000).

Despite the popularity of PjBL in secondary mathematics and science 9-12 grade classrooms, most of the studies involving secondary teachers were part of some intervention or had a research-based university partnership association (Han et al., 2015; Lotter et al., 2020; Saavedra et al., 2022). Others specifically considered the impact of professional development on implementing and enacting PjBL in secondary classrooms (Farrow et al., 2022). Apart from this research agenda, other scholars have investigated PjBL implementation from a teacher perspective. For example, Wilson's (2021) qualitative study that identified enablers and constraints in delivering science, technology, engineering, and mathematics (STEM) PjBL in an Australian secondary school located within a diverse, socio-economically disadvantaged community calls for purposefully "scaffolding the capabilities of teachers and students to engage with active learning; and the potential value of multi-dimensional assessment allowing students to demonstrate STEM proficiency through novel forms of evidence" (p. 881). Morrison et al. (2021) on the other hand using qualitative methods investigated how teachers' support, guidance and challenges related to elements defining students' learning experiences in a project-based STEM high school. This study specifically recommends teacher preparation to provide "preservice teachers with authentic experiences, celebrating failure as part of learning, explicitly teaching about PjBL pedagogy, and stressing the importance of caring relationships and 21st century competencies" (p. 1103).

Significance

Thus, in most studies the emphasis has been on the impact of PjBL on the benefits for students' learning of science and mathematics content or solely based on the relationship between specific contexts (community perspectives) (Wilson, 2021) or project-based STEM high school and PjBL (Morrison et al., 2021) however, the focus on teachers' experiences with PjBL implementation is largely neglected. This is an important area of focus since PjBL as an inductive instructional approach, heavily dependent on student-centered methods, is seen as a pedagogical shift for teachers who otherwise are dependent on orchestrating students content knowledge construction through traditional instructional approaches (Farrow et al., 2022). Thus, there is a need to build knowledge about teachers' experiences with this pedagogical shift to students' learning of science and mathematics content through PjBL as an inductive instructional approach. In this study we specifically investigated novice secondary mathematics and science teachers' developing beliefs about PjBL in authentic 9-12 science and mathematics classroom settings, respectively.

Problem Statement

This study was pertinent to the authors' instructional context and research agenda as the authors were course instructors within a secondary teacher preparation replicating the UTeach program. The program specifically recruits STEM majors and prepares them to become secondary school mathematics and science teachers and PjBL is a required course taken by all pre-service secondary teachers. Thus, for authors of this study an investigation of the teachers graduating from the program, specifically their beliefs about PjBL as novice teachers contextualized from within their authentic 9-12 authentic classroom settings aimed to provide feedback to the development of the pre-service teacher education PjBL course that was part of the novice teachers' professional development as secondary teachers. We focus on beliefs because both current (Mansour, 2013; Wong & Luft, 2015) and past (Pajares, 1992) research have continuously indicated that teachers' beliefs are one of the key determinants in their decision-making for using teaching practices and how to teach. Additionally, the significance of such a study contributes to the knowledge base related to the progressive development of PjBL in K-12 education and teacher education and is pertinent because research has continuously related how classroom practice leads to experiences that then develop into beliefs and how these beliefs in turn influence the future utilization and/or integration of instructional methods like PjBL (Lotter et al., 2020). The purpose of this study was to identify novice teachers' beliefs about their implementation of and instruction with PjBL as they transitioned their knowledge of PjBL as practice to knowledge of PjBL in practice in authentic secondary science and mathematics classrooms. The research question that guided this study was: What are novice secondary mathematics and science teachers' developing beliefs about their implementation of PjBL in authentic 9-12 classrooms? This study is part of a larger study on novice teachers' planning and implementation of PjBL (Harrell et al., 2024).

LITERATURE REVIEW

PjBL in Mathematics and Science Education

A review of the recent mathematics education (Chen & Yang, 2019; Han et al., 2015) and science education literature (Krajcik & Shin, 2014; PBLWorks, 2022), respectively make several claims about the benefits of teachers utilizing PjBL as an instructional method for student learning in mathematics and science. The literature claims that when teachers provide a contextualized project-based curriculum their students' interest, motivation, persistence, and self-efficacy to learn content is evident and this then leads to improvement in students' content knowledge, performance on standardized assessments, retention of content knowledge, and their development of 21st century skills (critical thinking, creativity, research practices, etc.) (Chen & Yang, 2019). The benefits of increasing affective, cognitive, and procedural outcomes among students is dependent on project-based curriculum and teacher PjBL teaching practices that provide students with

(a) authentic and relevant challenging problems and questions related to students' home, local, and community contexts and
(b) the autonomy to make decisions and choices for solving problems and questions (Almulla, 2020; English & Kitsantas, 2013; Thomas, 2000).

Other important student learning benefits include students' understanding of group work as productive work in solving problems because of the emphasis on argumentation, providing and accepting feedback among peers, role of time management, practicing leadership roles, and engaging in multimodal communication skills. Overall, the consensus is that students positively associate themselves with PjBL as an inductive teaching method for their learning outcomes, but this is dependent on the contextualized project-based curriculum, and PjBL teaching practices (Larmer & Mergendoller, 2015; PBLWorks, 2022; Thomas, 2000). This consensus also highlights the differences between PjBL and PBL. For instance, Ribeiro (2011) contends that PBL in adversely impacts routinization and constrains teachers' autonomy but Ribeiro (2011) does point out that such new approaches to instruction also impact teacher's knowledge base for instruction and thus an area that needs further study.

An additional claim in the mathematics education and science education literature is that a contextualized project-based curriculum supported by PjBL teaching practices provides underserved minoritized students across ethnic, locale, and grade levels with increased access to STEM education (Lotter et al., 2020; Wilson, 2021), and thus, accentuating the credibility of PjBL as a teaching method for equity in STEM education (Craig & Marshall, 2019; Morrison et al., 2021). Despite the benefits of PjBL expressed in the literature, scholars argue that pressures of standards-based state testing and strongly held beliefs like learning as teacher-centered may contradict the benefits of PjBL (Farrow et al., 2022; Lotter et al., 2020). In contrast, literature also contends that when supported with educative curriculum and professional development (Ravitz et al., 2012) teachers will have success with PjBL and see the benefits of PjBL.

Frameworks

Gold standard PjBL

According to the literature the gold standard (Larmer & Mergendoller, 2015) PjBL reflects the comprehensive research-based model of PjBL. This model is composed of three parts that are student learning goals, essential project design elements, and project-based teaching and which individually and collectively provide the constructs to measure, calibrate, and improve PjBL and thus, explicate the rigor of PjBL in action. The following synopsis of gold standard PjBL is derived from both current (Farrow et al., 2022; Grossman et al., 2019; PBLWorks, 2022; Wallace & Webb, 2016) and past (Ravitz, 2008; Thomas, 2000; Thomas et al., 1999) literature about PjBL.

Student learning goals: Student learning goals are the core of PjBL because the goals emphasize academic content and skill development and thus put the focus on the project to accomplish the goals leading to student learning outcomes and academic achievement. The project anchored by student learning goals is framed by key knowledge and conceptual understanding. This focus characterizes the rigor of PjBL and, thus, its instructional effectiveness in teaching content knowledge through application of the content knowledge in constructing authentic products for solving problems and answering complex questions. The application of content knowledge and conceptual understanding constructed through the project is also intended to focus students onto successful skills (critical thinking/problem solving, collaborations and project management) that are competencies (21st century skills, college and career readiness skills, and workplace skills) for future success.

Essential project design elements: A gold standard PjBL instructional approach has a successful project encompassing seven design elements that maximize student learning and engagement (Wallace & Webb, 2016). Each of the seven design elements and how they maximize student learning and engagement is summarized below:

1. Challenging problems or questions engage students with meaningful knowledge enabling them to investigate and answer the problem or question.
2. Sustained inquiry that engages students in long term projects requiring them to use a variety of information sources.
3. Authenticity relates back the nature of challenging problems or questions which is situated in real-world settings, familiar and empathetic to students' lives, requiring real-world resources to investigate and answer.
4. Student voice and choice relates to the idea of student input and control in making decisions on what resources, and roles to be used to investigate and answer the challenging problem or question and the resulting product or presentation that supports the response to the challenging problem or question.
5. Reflection is about how students together with their teacher formally or informally relate back to process and product of the project underpinning the challenging problem or question to seek feedback on "what they are learning, how they are learning, why they are learning, on the project itself and how to move forward"
6. Critique and revision are tailored into the long-term project in the form of constructive peer (student to student) supported by "rubrics, models, or formal feedback/critique protocols"
7. Public product refers to the tangible product or presentation constructed or designed in response to the challenging problem or question and is a meaningful outcome highlighting students' engagement with the content.

Project-based teaching practices: Teaching practices that exemplify the gold standard PjBL approach are closely related to both the student learning goals and essential design elements and relate to teachers' implementing PjBL by:

1. Designing and planning projects that relate to their students' school and community-based contexts and guide the projects from start to culmination with pertinent and collaborative input and feedback from their students.
2. Aligning the project to state or national standards and thereby addressing the essential and key goals and objectives for subject/content mastery.
3. Building a classroom/school culture that directly and indirectly fosters students' attributes for inquiry, quality and promotes student independence, student collaboration and student cooperation.
4. Managing activities that build student attributes for tasks (using resources, creating, and showcasing the products to content mastery) and time organization skills (adhering to checkpoints and deadlines).
5. Scaffolding students learning through differentiation in lessons, resources, and instructional strategies to support all students to attain project goals.
6. Assessing student learning for knowledge, understanding, skills, success and content mastery through self and peer assessments that are differentiated into formative and summative assessments.
7. Engaging and coaching students in collaborative ways to identify and thus facilitate students' needs for skills-building, redirection, focus, and success in attaining project goals.

Even though the literature conceptualizes PjBL as three separate entities student learning goals, essential design elements, and teaching practices, Farrow et al.

(2022) have reconstructed these goals, elements, and practices into two key foci: structure-driven practices and purpose-driven practices. From Farrow et al.'s (2022) perspective structure-driven practices are specific to the project focus and are supported by the teaching practices of engaging students in work on projects, explaining project expectations to students, and connecting lesson components to the project. The purpose-driven practices, on the other hand, are governed by the individual goals supported by its own specific teaching practices:

1. Disciplinary goals that include teaching practices engaging students in inquiry and talk specific to the discipline embedded in the project focus.
2. Collaboration goals that include teaching practices supporting students to collaboratively make decisions.
3. Authenticity goals that include practices supporting students to make meaningful and personal connections to the project focus and see the relevance of the project to their community and the world.
4. Iteration goals that include teaching practices aimed at supporting students to provide and receive feedback on the project and aimed at providing support for students to reflect and revise their projects based on given and received feedback.

In sum, the literature on gold standard PjBL posits the project-based component as central to the course curriculum, instruction, and student learning (structure-driven practices) and based on student-centered and inquiry-driven design principles and engages students in authentic, relevant and meaningful learning experiences that are designed to solve real-world problems (purpose-driven practices) (Farrow et al., 2022; Hsin & Wu, 2021; Morrison et al., 2021; Wilson, 2021).

Beliefs

It is widely acknowledged in the literature that teacher beliefs are important factors in teachers' classroom decisions in relation to instruction and student learning (Donnell & Gettinger, 2015; Sansom, 2020). Literature has continuously alluded to the role of teachers' beliefs in their planning of lessons and the instructional (teaching and learning) activities that happen in their classrooms. Directly and indirectly teachers' decisions on what to teach, how to teach, and when to teach topics as stipulated in the curriculum are subject to and governed by their beliefs. For instance, Skott (2015, 2022) contends that beliefs underscore teacher's explanations of their classroom actions and hence the meanings that make out of these classroom actions. Apart from this, Skott (2022) claims that subject-related beliefs are prone to educational concerns inherent in classrooms and thus beliefs can be inevitably challenged and discarded and/or strengthened. Hence, it is acknowledged that the school culture and institutional constraints (state/national mandated standards/curriculum, state testing, etc.) either scope, limit, delimit or modify beliefs which in turn counteract their pedagogical approaches learned from experience, professional development, and/or teacher preparation courses. The literature also contends that experiences lead to the development of beliefs which then become part of the individual's belief systems (Hwang et al., 2018; Pajares, 1992). These systems in turn play a critical role in how the individual interprets past, present, and future experiences (Hwang et al., 2018), and thereby serve, guide, assist, and define how the individual comprehends their context, behavior and actions (Pajares, 1992). Apart from how and why beliefs develop there is literature arguing for the categorization of beliefs, that is, seeking different taxonomies for teachers' beliefs (Xenofontos, 2018). In this study we address teachers' beliefs from the standpoint of professed and enacted beliefs as evoking a traditionalist/transmissionist perspective (process and products of student learning are teacher-centered) or a constructivist perspective (process and products of student learning are student-centered with teacher facilitation, guidance, and motivation). Based on the above arguments we also posit that we consider mathematics and science teachers as a uniform group by discussing both the similarities between PjBL and teacher beliefs in these domains. Moreover, we have to add that the teachers' professional learning of PjBL was not domain specific to either mathematics or science and thus, they all were exposed to the same generic knowledge base that framed the PjBL course taken during their secondary teacher preparation program.

Crucial to the study of teachers' beliefs (analyzing and understanding) is the need to be cognizant of the dialectical relationship between beliefs that are professed and beliefs that are in practice (Zhang & Morselli, 2016). In view of this conundrum in the literature, scholars propose qualitative methods like interviews, focus groups, and observations (Mansour, 2013; Pajares, 1992; Subramaniam, 2013; Wong & Luft, 2015). The resolution here is to identify beliefs from teacher's interpretations of their experiences and to establish and distinguish and/or to seek coherence between espoused beliefs and enacted beliefs. In summary, we propose that beliefs that novice teachers are developing are derived from actual experiences based on their current 9-12 teaching in authentic classrooms.

METHOD

Participants

Ten first year/novice secondary school teachers took part in this study. All participants volunteered to take part in the study. Of the 10 participants, four participants taught mathematics, and six participants taught science. All participants who taught in secondary school settings were assigned to teaching that spanned different grade levels (grade 9-grade 12). The ethnicity of the participants was determined using university records where ethnicity is self-reported: 10% Asian, 9% Black, 21% Hispanic, 52% White, and 9% did not report their ethnicity. All participants identified themselves as novice teachers with more than one year and less than two years of in-service teaching experience. The participants who taught mathematics received a degree in their content area, such as a BA mathematics, and those participants who taught biology received a BA in biology, BA or a BA in chemistry along with a minor in education that included teacher certification. Participant GPAs were a minimum of 2.8 on a 4-point scale, a condition of Council for the Accreditation of Educator Programs (CAEP) accreditation. Participants were selected because of their preparation as an undergraduate, and their content expertise in science or mathematics.

Contexts: Teacher Preparation and In-Service

Teacher preparation

All participants in this study attended a secondary teacher preparation program situated in an R-1 university that is CAEP accredited. The secondary teacher preparation program is one of 11 original UTeach replication projects that received five years of financial support and extensive feedback from UTeach. The UTeach program specifically recruits STEM majors and prepares them to become secondary school mathematics and science teachers. The program combines STEM degrees with secondary teaching certification without adding time or cost to four-year degrees. The PjBL course (project-based instruction in math, science, and computer science) is part of this replication and participants in this study like their counterparts in other UTeach replication sites completed a 45-hour course in PjBL. Project-based instruction in math, science, and computer science also included significant field experiences in a PjBL school. Other courses part of this secondary teacher preparation program included inquiry approaches to teaching (STEP 1), inquiry-based lesson design (STEP 2), conceptual algebra and geometry, knowing and learning in mathematics and science, classroom interactions (CI), and student teaching in mathematics and science (apprentice teaching). Participants in this study were taught by teacher educators who had both teaching and research expertise in STEM fields, in STEM teaching and learning, and in the history of science and mathematics.

In-service

Almost all participants mentioned that they taught in block or flexible school settings (87%) where there was emphasis on problem-based, project-based, or inquiry learning (76%) and on acquisition of 21st century skills (100%). Participants also indicated that their work as novice teachers in their respective school settings included instruction time for PjBL: Seven teachers (68%) indicated they spent 25% or less instruction time using PjBL. Three teachers (12%) indicated they spent approximately 50% of instructional time facilitating PjBL with an equal number spending 75% of their time, and two teachers (8%) used PjBL exclusively for instruction. Participants also mentioned that outside of the professional learning in PjBL they received as a pre-service teacher, little professional development was provided during their current role as in-service teachers.

Data Collection

Focus group interviews were utilized in this study to identify participants' developing beliefs about their implementation of PjBL in their authentic secondary science and mathematics classroom settings. Two focus groups were conducted with participants, exploring their experiences of implementing PjBL in their authentic classroom settings. Focus group interviews enabled the researchers to gather data in a social context (Krueger & Casey, 2009) that highlighted participants' implementation and shared vision and goals for their use of PjBL for instruction and student learning. Two separate focus groups were conducted: one for participants who taught science and a separate focus group for participants who taught mathematics. The focus group interview questions included:

1. What is the difference between problem-based instruction and project-based instruction, just as you understand it?
2. Do you follow a scope, and sequence at your school?
3. How fixed are the timelines for a unit on a topic?
4. How frequently do you utilize PjBL practices in your instruction?
5. What role does testing play in the amount of PjBL instruction you might utilize?
6. What role does testing play in the use of PjBL? and,
7. What challenges do you see preventing the utilization of PjBL practices in your classroom, so what challenges?

The use of focus groups enabled the collection of participants' rich descriptions about their experiences with implementing PjBL. According to literature, the utilization of focus groups provides researchers access to deeply held beliefs that individual interviews or surveys might not identify (Krueger & Casey, 2009).

Table 1. Distribution of beliefs (themes) for confirmation/disconfirmation (X: Indication of belief/s as identified by each author)

Identified beliefs from analysis	Investigator triangulation			Intercoder agreement (%)
	Author 1	Author 2	Author 4	
Theme 1. Beliefs about how students learn with PjBL implementation				
• Disconnect between PjBL and student mastery of content	X	X	X	100
• Disconnect between PjBL and student abilities	X	X	X	100
• PjBL and positive student learning outcomes	X	X	X	100
Theme 2. Beliefs about instruction with PjBL implementation				
• PjBL and instructional time	X	X	X	100
• Disconnect between PjBL and scope and sequence of curriculum	X	X	X	100
• Disconnect between PjBL and state mandated testing	X	X	X	100

Furthermore, focus groups provide safe and collective comfort zones wherein participants can interact, reconcile, and expand upon beliefs stated or conflicting beliefs in data collection techniques like individual interviews or surveys (Krueger & Casey, 2009).

Data Analysis

An inductive thematic analysis approach (Braun & Clarke, 2006) was adopted by analyzing the two sets of transcripts from each of the two focus group interviews. Thematic analysis in this study was used to interpret discernible patterns inherent within participants' meanings of implementing PjBL in their classrooms. Both transcripts were analyzed by three of the five authors of the study. In this study, thematic analysis involved the familiarization (reading and re-reading) followed by coding extracts within the transcripts to identify preliminary beliefs in view of the context and descriptions within which the belief was identified and coded. The codes together with identified preliminary beliefs, context and descriptions were categorized to seek coherent and meaningful beliefs about teaching with PjBL. For instance, synopsis of gold standard PjBL is derived from both current (Farrow et al., 2022; Grossman et al., 2019; PBLWorks, 2022; Wallace & Webb, 2016) and past (Ravitz, 2008; Thomas, 2000; Thomas et al., 1999) literature about PjBL were used to seek coherence with descriptions of teaching practices and beliefs in both participants' descriptions of their mathematics and science classroom instruction (contexts). An example here was to seek coherence with participants' descriptions of in-class PjBL and its by alignment with state or national standards and thereby addressing whether the essential and key goals and objectives for subject/content mastery was met with PjBL. This provided and consolidated participants belief that the integration of PjBL inadvertently has limitations and thus impacts state-mandated testing.

The beliefs about teaching with PjBL were then reworked into all data extracts across the data to seek context and descriptions that added to, confirmed, disconfirmed, expanded upon and/or clarified the identified beliefs. Investigator triangulation (Guion et al., 2011), and intercoder agreement (Kurasaki, 2000) were used as a trustworthiness technique in this study. Three of the four authors independently analyzed the focus group data and preliminary themes from their individual thematic analysis were compared to seek consensus on the identification of themes. In addition to seeking agreement on consensus on preliminary themes, the three authors consulted each other about how they applied codes to the focus group transcripts. In seeking consensus for shared themes, the three authors of the study sought to correspond the shared themes to participants' constructions of implementing PjBL in their classrooms as expressed in their focus group interview transcripts. **Table 1** shows how beliefs were worked across the two data sets (focus group interview transcripts) to seek coherence and/or incoherence.

FINDINGS

Beliefs About How Students Learn With PjBL Implementation

Analysis of focus groups data indicated that participants believed that their students were not going to master the content through the utilization of projects. They believed that PjBL was not structured to enable students to learn content that was needed for state-mandated testing. This belief was closely aligned to their apprehension of not preparing their students to master the content and the apprehension that projects would not enable students to learn concept and/or vocabulary and associated concepts and vocabulary needed to pass state-mandated testing. This was exemplified by the following quotes from participants:

> And then on top of that, being biology, there's so many minor vocabulary words that have to be learned in the unit, and as much as I'd like to say you have a week to do a project, if they don't learn the right words during the project, that could be a problem on the state mandated testing, when the state mandated test asks a question and oopsie daisy, the kids didn't find that one. They never did that word. Now they get that question wrong (George, 10th grade biology teacher).

> They get it wrong on the test wrong, on the state mandated testing, and even though they learned a million other things about the content during their projects, it wasn't the right thing, according to what is required for the state mandated testing. And so that's my biggest issue and why we just don't use it because it would take too much time and you can't guarantee they're gonna hit the right stuff (Amy, 11th grade mathematics teacher).

Apart from this belief, there was a category of beliefs closely associated with how students learn with PjBL implementation. This category of beliefs was closely aligned with their students' abilities in relation to participants' utilization of PjBL for instruction. For example, participants claimed that their students lacked experience or skills necessary for PjBL:

> I've taught a regular biology classroom, in which we didn't really do a lot of projects or PBL. I think it was mostly out of fear that the kids were not at the level where they could do it successfully (Sean, 10th biology teacher).

> … because another problem I have with projects is there are those kids that don't wanna work, and they ruin it for the other kids, and it's hard … it's hard when you're doing these projects for the first time. Trying to find that balance between making it fair for the kids, keeping all working, keeping it on task, and you feel like–I remember I did one project. It wasn't even a big one (Vickie, 10th grade mathematics teacher).

On the other hand, participants claimed that PjBL was more appropriate for students with high abilities compared to students with lower abilities. For instance, "Only use it with pre-AP" was a common consensus among participants. Participants echoed the consensus of the suitability of projects with high ability students.

> I think, with 11th and 12th graders at that level, because those were the high achieving kids too on top of that. And so, it's harder when you're dealing with ninth graders, who barely, you know, like, homework, ooh, maybe (George, 10th grade biology teacher).

Beliefs About Instruction With PjBL Implementation

Focus group data which drew on participants' interpretations of their actual experiences with their implementation of PjBL indicated that participants drew on their experiences of how time consuming PjBL implementations were and how this in turn made them question the validity of such an instructional activity for enabling students to construct the intended learning outcomes. For instance:

> I feel like a lot of the time students aren't retaining the information that we've covered in the past, so we're constantly spiraling in old information with new information and so a lot of the time–I spend a lot of the class time reviewing before we can move on. So, it makes it harder, the time constraint, to do PjBL (Victor, 10th grade mathematics teacher).

> You can't just give a kid a project, especially not a freshman. I'm a biology teacher. I teach freshman. You can't give a freshman a project and say, "Here, come do this." It has to be a guided thing, and I think that people lose sight of what PjBL is. I have to make sure that I am somehow making sure that this student is running into that vocab that I need for them to cover. I need to take the responsibility and make sure that students are running into these things, and I need to make sure that they're experiencing those things that I need them to get out of this. And I don't think that it's impossible. I just do know that it does take time (Kenneth, 10th grade biology teacher).

The disconnect between PjBL as an instructional practice was exacerbated by both the school context and classroom contexts, respectively, within which participants and their students were situated. This belief was influenced and governed by school administrators and by school subject department cohorts, respectively. For example:

> I saw that in the algebra team, they did not want to deviate from how we've taught it in the past. It worked before. It'll work again. Why should we do something new? See, sometimes our administration looks at me and goes, "Well, researching, writing, presenting, these aren't covering the state standards needed for testing" (Jennifer, 9th grade mathematics teacher).

> Our administrators eat, breathe, and sleep state mandated testing. They wake up in the morning and they say, "state standards and testing" so every meeting, everything we do is about how many days do we have for this? (Carlos, 11th grade chemistry teacher).

At the classroom context level this belief about beliefs about how students learn with PjBL implementation was influenced and governed by the scope and sequence of the curriculum as mandated by the school district and state standards. For instance:

> We are responsible for the state testing for biology, so we do follow scope and sequence. We're allotted a certain number of days per each standard for Biology and each Biology topic to

cover, so yes, we stick to that like our life depends on it (Steven, 10th grade biology teacher).

Also, the scope and sequence. A lot of times, again, there were some constraints. It's like, okay, but you should be covering this topic, you know, or this information now, whereas maybe the PjBL I'm planning is covering something maybe they've done kind of in the past or maybe we haven't even got to yet, and it just–just no one worked to implement it. Sometimes it throws it off (Stephania, 11th grade mathematics teacher).

In addition to these personal beliefs, participants believed that external factors impacted their utilization of PjBL for instruction. These included testing and accountability requirements, "parents or students expected me to use direct instruction", "students had poor attendance" and/or "behavior problems", students lacked experience or skills necessary in PjBL, limited classroom space, limited timing in blocked schedules, and large class sizes. For example, participants expressed that rigid testing and accountability requirements was a challenge to implementing and enacting PjBL:

We have a state-mandated biology exam, so we do have to follow scope and sequence to prepare students for this exam. We're allotted a certain number of days per each objective for each topic, so yes, we stick to that like our life depends on it (Tom).

I think almost everyone at this table's going to say something, the similar biology state-mandated exam. Our administrators eat, breathe, and sleep for this exam. So, every meeting, everything we do is about how many days do we have to prepare for this exam (Sally, 9th grade biology teacher).

I would think within our department, rigid towards administration. So, our administration's more like when we walk in, we want everyone on the same page, every single day. We want to know that if we look at the scope and sequence, this is what you need to be. And we're more like, department-wise, it's okay if we're a little off for a few days because we know it needs to be done, but we still have that pressure of the rigidness (Miranda, 10th grade mathematics teacher).

Participants also expressed that their school setting was not enabling them to implement and use PjBL. For instance:

I'd like to add too, that in my campus, we have to do the same major grades, and so whether that be a test or a project in getting the other geometry teachers on board to do the same project, to keep it streamlined across the campus is a little bit of a pushback sometimes, because it's easier to just give them a test and grade that and get data from that, rather than having them take the time to do it in class and then looking at the project and spending the time on it (Samuel, 10th grade mathematics teacher).

In addition to the above contextual factors influencing and governing this belief, participants believed that they lacked professional development or coaching in PjBL, time in the curriculum to complete projects, time to plan, create, or find quality projects, models, or examples for using PJBL in their subject area with their students, and funds, materials, or resources. The following quote for example illustrates the concern with the lack of adequate professional development:

We always kind of review all the topics with a PjBL project, but I think it's also just the fact that the confidence I guess that I have to perform a PjBL project and making sure that all my students hit those objectives for the state-mandated STAR exams that they have to take. And I teach ESL students, so kind of having them practice to meet you at that level to do projects, there's just not enough time for that, and then maybe if I had more confidence in knowing how to structure it so that I could hit all the points that they need to, I would be a lot more willing to try it. But it's just the pressure of staying on a schedule and the lack of confidence, knowing how to meet that level and how to hit those exact points that I need to, to make sure that it's working properly (Adam, 9th grade biology teacher).

DISCUSSION

What are novice secondary mathematics and science teachers' in authentic 9-12 classrooms? This study is part of a larger study on novice teachers' planning and implementation of PjBL (Harrell et al., 2024).

The purpose of this study was to identify novice teachers' beliefs about their implementation of and instruction with PjBL as they transitioned their knowledge of PjBL as practice to knowledge of PjBL in practice in authentic secondary science and mathematics classrooms. As mentioned, two beliefs,

(a) beliefs about how students learn with PjBL implementation and
(b) beliefs about instruction with PjBL implementation, were predominant in participants' experiences with the implementation of PjBL into their classrooms for teaching mathematics and science, respectively.

Participants' beliefs about how students learn with PjBL implementation were expressed from the participants' perspectives of their students' abilities, that is, PjBL was inclusive to AP students or high achieving students and not suited for low ability students. Overall, this belief was governed by participants who need to prepare their students to pass state mandated testing, but the beliefs and supporting perspectives indicate that participants were not conceptualizing PjBL from the constructs of the gold standard PjBL, specifically the construct of student learning goals (Larmer & Mergendoller, 2015; PBLWorks, 2022) or to what Farrow et al. (2022) refer to as the purpose-driven practice of discipline goals. In fact, it was obvious from the findings that for participants in this study PjBL was not seen as a process to attain student learning goals but as a product.

The notion of state-testing as an end-product or end outcome seemed to override the conceptualization of the PjBL's purpose-driven practices of discipline goals, collaboration goals, authenticity goals, and interaction goals. In this study, the project seemed to be equated to the student learning outcomes as stipulated in the state-mandated standards, scope and sequence of the curriculum, and state-mandated testing. That is, solely, connecting the project to student mastery of intended content and not the process of meaningful learning as posited by scholars in the literature (Larmer & Mergendoller, 2015). In other words, participants were not conceptualizing their students' learning with PjBL from a contextualized perspective which in this case contradicts the contention in both the mathematics education literature (Chen & Yang, 2019; Han et al., 2015) and science education literature (Krajcek & Chin, 2014; PBLWorks, 2022; Rogers et al., 2011) that emphasizes a contextualized project-based curriculum anchored in students' interests, motivation, persistence, and self-efficacy to learn.

Developing Beliefs About Implementation of PjBL

Moreover, participants' beliefs about how students learn with PjBL implementation as expressed from the participants' perspectives of their students' abilities, questions their understanding of PjBL as a teaching method for equity in STEM education. Participants' beliefs about PjBL and students' abilities in this study contradicts the contextualized project-based curriculum attribute of PjBL (Craig & Marshall, 2019; Morrison et al., 2021) and the supports it provides for equitable classroom by relating disciplinary ideas to the construction of authentic artifacts or solutions as stated in the literature (Al-Balushi & Al-Aamri, 2014; Hsu et al., 2015; Miller et al., 2021; Tashtoush et al., 2025).

Participants' beliefs about instruction with PjBL implementation were expressed from the participants' perspective of teachers who are the transmitters of the knowledge while students act as the receptors of the knowledge imparted by teachers. Findings indicated that the pedagogical shift that is expected with the implementation PjBL (Farrow et al., 2022; Morrison et al., 2021; Pan et al., 2022) was limited due to participants' perspective of teachers as transmitters of knowledge and students as receptors of that knowledge. Although this can be attributed to the time constraints, mandated scope and sequence of the curriculum, state-mandated testing, and pressure to conform to the aforementioned factors by administrators and peers, it points to how beliefs impact pedagogical shifts. Consequently, no matter what the established and espoused benefits are for a proposed inductive instructional method like PjBL, it is evident from the findings in this study that the school and classroom contexts govern teachers' experiences and the experiences than influence and impact established and/or developing beliefs.

Role of Beliefs and Implementation of PjBL in Teacher Education

For the authors, the intent of the study was to investigate participants' beliefs about their implementation of PjBL and how these beliefs can be used as a lens to provide feedback to the development of the pre-service teacher education PjBL course that was part of participants' professional learning as secondary teachers. As evident from the findings there was a misalignment between participants' beliefs about learning and teaching with PjBL. This misalignment cannot be solely referenced to the school and classroom contexts participants are currently situated in. It is argued here that the PjBL experiences gained through coursework and field experiences at PjBL-based secondary schools, knowledge of practice for PjBL cannot compare to authentic experiences in school and classroom contexts. In other words, a subset of experiences, (coursework and field experiences), are not relatable to the 180 or 190 hours of instruction in authentic settings. In view of dilemma, a progressive development of PjBL in K-12 education and teacher education is needed. This development can be a change in beliefs in relation to pedagogical shifts in conceptualizing PjBL in both teacher education and in-service professional development.

CONCLUSION

This study sought to identify beliefs about teaching and learning of novice secondary mathematics and science teachers when they implemented PjBL in their classrooms. A key implication from this study is that the pressures of standards-based state testing and strongly held beliefs like learning as teacher-centered contradict the benefits of PjBL as mentioned in the literature (Farrow et al., 2022; Lotter et al., 2020). PjBL as an inductive instructional method with a specific focus on active learning and PBL to transform secondary mathematics and science education as advocated by NGSS Lead States (2013) and NCTM (2014) needs to take into the knowledge of teachers' thinking of PjBL. It is important that professional learning in teacher education programs and professional development in schools acknowledge and reflect on the beliefs that drive instructional practices like PjBL in classrooms.

Implications

Most importantly, there is a need to conceptualize a complex perspective of PjBL from school and classroom contexts. This includes moving away from conceptualizing PjBL as a set of procedures to conform to classroom practices. The framework suggested by Farrow et al. (2022) with two key foci, structure-driven practices and purpose-driven practices provides one such move since it is specific to the project focus and is supported by the teaching practices of engaging students in work on projects, explaining project expectations to students, and connecting lesson components to the project: meaningful learning with PjBl emphasized as a process and product rather than procedure. In addition, findings in this study posited teachers' thinking of PjBL from their perceptions of state-mandated standards and testing, and the prescribed scope and sequence for day-to-day/week-to-week instruction. This points to the unclarity between what standards are (what students are expected to know at the end of the semester/school year and/or grade level) and what is a curriculum (the means to fulfill the standards). Therefore, there is a need for both professional learning in pre-service teacher education and professional development in in-service teacher education on clarifying instructional decisions about utilizing PjBL as a means to student learning.

Limitations

The authors of the study understand that the findings from the analysis of two focus groups might not be generalized to other populations of secondary mathematics and science teachers implementing PjBL. The tendency to report their actual lived experiences, in this case investigating PjBL implementation through focus groups, may lead participants to either overestimate or underestimate the student learning benefits.

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