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Integrating community assets, place-based learning, and career development through project-based learning in rural settings

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Our study investigates the first year of a two-year place-based education (PBE) professional development model that focuses on career development in rural middle schools through project-based learning (PBL) units. Rural science, technology, engineering, and mathematics (STEM) educators face unique challenges, including geographic isolation, limited resources, and reduced access to professional development opportunities, which can hinder the effective integration of career-oriented learning in the classroom. We addressed these challenges by implementing professional development in which school counselors and teachers collaborate to design PBL units aligned with rural community local needs and STEM careers. Using a descriptive multiple-case study methodology to document the experiences of three teams of educators, we used cross-case analysis to explore how the teams integrated PBL and PBE principles to foster meaningful learning experiences and enhance career awareness among students. The research questions focused on each team's implementation of the PBL units based on key PBL design elements and how they integrated local community connections and places. Initial findings suggest that while teams effectively engaged with community members and integrated STEM career connections, they faced challenges in broadly applying learning and assessment practices. We highlight the potential of PBE to enhance rural STEM education and emphasize the need for long-term professional development to equip teachers with the skills necessary to integrate STEM content and career development effectively.

KEYWORDS

project based learning (PBL), place based education (PBE), professional development (PD), rural education, science technology engineering mathematics (STEM), school counselors (SC), teachers, community integration

Introduction

Rural science, technology, engineering, and mathematics (STEM) education presents unique opportunities and challenges shaped by geographic isolation, limited access to resources, and a strong connection to local communities (Showalter et al., 2023). Despite the growing importance of STEM careers in the global economy, rural teachers often lack the professional development (PD) needed to effectively integrate career development into their instruction (Howley and Howley, 2005; Johnson, 2006). This issue is exacerbated by the infrequent and undervalued collaboration between teachers and school counselors, especially in rural areas (Limberg et al., 2019; Emihovich and Battaglia, 2000; Reiner et al., 2009). To address this gap, we partnered with rural middle schools to implement a multi-year PD program to enhance STEM career integration with community-infused project-based learning (PBL) units.

Our research study describes teachers' PBL unit implementation after experiencing the first year of a two-year professional development model that engaged teams of educators in developing STEM PBL units with local community and career connections. Using case study methodology, we present three rural educator teams' experiences implementing their PBL units. Two research questions guided our research:

1. How do the educator teams' implementations of PBL units reflect key PBL design elements in rural settings?
2. In what ways do the educator teams integrate local community assets and STEM career opportunities into their rural place-based PBL units?

Our study contributes to understanding how rural-focused approaches can bridge the gap between rural education's unique needs and the universal goals of STEM education.

Theoretical framework

Our Advancement of the Workforce and Knowledge Economy for STEM (AWAKE-STEM) PD program was developed using two theoretical frameworks: (a) Social Cognitive Career Theory (SCCT; Lent et al., 1994) and (b) STEM Workforce Education Logic Model (STEM-WELM; Reider et al., 2016). SCCT suggests that a student's career choice is determined by their perceived outcomes, level of interest, and career self-efficacy. SCCT is based on the notion that a student's self-efficacy will determine whether the student will choose to participate in a task. In other words, students with high self-efficacy, or strong belief in themselves regarding a specific subject or activity, will influence the student to continue and increase their participation in experiences related to the subject or activity.

Career-self efficacy is influenced by a student's personal characteristics (i.e., ethnicity, gender) and environmental factors (i.e., family dynamics, educational setting) and impacts their perceived career outcomes, career interest, and overall career choice. In our study, the educators designed and provided students opportunities to actively engage in STEM experiences using PBL to increase their self-efficacy by taking ownership and leadership of their learning. The other theoretical framework, STEM-WELM, suggests that enhancing students' entry into the workforce requires combined exposure to STEM content and career development. By design, PBL integrates both STEM content through coursework and STEM career development activities that actively and authentically involve students in various aspects of the STEM workforce.

These frameworks were supported by authentic gold standard PBL design elements (Larmer et al., 2015), Steinberg's (1998) 6 A's framework, and PBE (Sobel, 2004). Gold standard project-based learning was designed by John Larmer, who brought together key aspects of William Kirkpatrick's "The Project Method" and John Dewey's philosophy of experiential learning (Ord, 2012) to create an "aspirational goal, a composite of the best research-based and classroom-proven project design elements and instructional practices" (Larmer et al., 2015, p. 34). Educators' use of the design elements in planning PBL units helps them "to enable students to develop the knowledge, understanding, and success skills that prepare them for successful school and life experiences" (p. 35). The seven Gold Standard Elements include challenging problem or question, sustained inquiry, authenticity, student voice and choice, reflection, critique and revision, and public product. This framework is further supported by Steinberg's 6 A's framework, which also originated from the philosophical roots of Dewey and Kilpatrick (Steinberg, 1998). Steinberg created the 6 A's Framework for Project-Based Learning to support educators in experiential and authentic learning by providing them with six key principles for designing and assessing effective PBL experiences. Table 1 describes each of the principles and the guiding question behind the assessment of that principle. This framework was used in a key assessment tool that will be elaborated on in the methodology section.

Finally, this theoretical framework is rooted in PBE. PBE further aligns this framework with the importance of education based on place and the surrounding community. In this case, the place is the rural communities where these schools are located. Sobel describes PBE as "the process of using local community and environment as a starting point to teach concepts…Emphasizing hands-on, real-world experiences…" (p. 6). PBE aligned with Authentic Gold Standard PBL elements and the 6 A's framework prioritizes real-world relevance and community integration, which enhances learning in rural education settings (Marietta and Marietta, 2020; Wahyuni et al., 2024). Professional development emphasizing the use of PBL design models (Larmer et al., 2015; Steinberg, 1998) and place-based elements (Sobel, 2004) supports teachers in developing curriculum units that meet their unique local needs, including connecting to rural contexts and specific student learning needs (Squire et al., 2003).

TABLE 1 Steinberg's 6 A's for successful PBL.

Design element	Guiding question
Authenticity	Does the project emanate from a problem that has meaning to the student?
Academic rigor	Does the project lead students to acquire and apply knowledge central to one or more discipline or content areas?
Applied learning	Does the learning take place in the context of a semi-structured problem, grounded in life and work in the world beyond school?
Active exploration	Do students spend significant time doing field-based work?
Adult relationships	Do students meet and observe adults with relevant expertise and experience?
Assessment practices	Do students reflect regularly on their learning using clear project criteria that they have helped to set?

From "Life's a Project: The 6 A's of Project Based Learning," by A. Larson, 2024, PBL Press.

Literature review

Rural defined

For our study, rurality is delineated by the NCES definition, which describes rural communities in three distinct categories: *rural fringe, rural distant,* and *rural remote* (NCES; Geverdt, 2019). Each of these is related to the distance the rural school or community is to an urbanized area. Even within the NCES definition of rurality, rural locations are compared to urbanized areas, potentially leading to the communities and experiences of students within rural schools being devalued (O'Connell et al., 2010). Regarding education, rurality can be defined as the unique set of challenges and opportunities faced by communities outside urban centers (Biddle and Azano, 2016), and understanding it requires recognizing the intersection of geographic, economic, and cultural factors that shape the educational landscape of rural communities (Bailey et al., 2014).

Throughout the U.S., many rural communities face economic challenges, geographic isolation, social isolation, and weaker community infrastructure when compared to non-rural communities, which can contribute to decreased student achievement while also limiting the amount of exposure to career opportunities (Griffin et al., 2011; Showalter et al., 2023). Carr and Kefalas (2009) note that with the isolation of rural communities from career development opportunities and mentorship, students are disadvantaged in accessing the necessary tools for unlimited career opportunities. Carr and Kefalas (2009) further note that as rural students progress academically and transition to higher education, they tend to leave the rural community and often do not return due to a lack of career opportunities, frequently referred to as rural brain drain. To combat the limited exposure to career opportunities, (Griffin et al., 2011) recommend school counselors take an active role in community partnerships and use community asset mapping to provide potential partnerships within their local rural community. Despite the preexisting challenges faced by rural schools, rural education receives limited attention from state policy and funding (Johnson et al., 2014).

Role of rural school counselors in career development

School counselors in rural schools play a pivotal role in addressing rural communities' unique challenges and opportunities (Grimes et al., 2013). School counselors address students' academic, career, and mental health needs (American School Counselor Association, 2019). Additionally, rural school counselors are involved within their local communities and work towards building trust and designing different learning opportunities for students to learn about their community (Grimes et al., 2013). Sanders et al. (2017) found significant variation in school counselors' confidence levels, with the highest self-efficacy in therapeutic skills and the lowest in multicultural competence and current career trends. Notably, these middle school counselors reported spending more time on non-counseling activities than on career counseling despite recognizing its importance. These findings highlight the need to prioritize career development in school counseling programs, ensuring students receive appropriate career instruction and exposure to diverse career opportunities. Given these challenges, collaboration with teachers and local community partners may be a valuable strategy to enhance career counseling efforts (Irvin et al., 2019). When exposing students to different career opportunities within their local community, place-based education has been identified as a practical approach to blending local career opportunities with lessons (Irvin et al., 2019). By incorporating place-based education into the classroom and incorporating real-world problem solving, rural students may see the value of staying local to their community. Birmingham and Calabrese Barton (2014) note that community-based science initiatives can empower students when taking responsibility for local issues such as pollution while also gaining insight into different career opportunities within the community.

While rural school counselors can guide students toward meaningful and local career opportunities, school counselors can also leverage community partnerships to provide students with mentorship and additional exposure to STEM careers and professionals. Nicholas and Scribner (2021) highlight the importance of incorporating STEM-professional volunteers into student lessons to increase student interest in STEM careers by ultimately offering hands-on experiences. By integrating different strategies into career development, school counselors can create more engaging and meaningful STEM career exploration opportunities for rural students. Ault et al. (2024) spoke to the importance of preparing school counselors to work in rural schools and emphasized discussing rurality as a unique cultural identity. Within rural communities, economic, religious, historical, and geographic facts combine to create a unique rural culture, and these factors have been shown to influence the mental, physical, and overall health of individuals within the community (Smalley et al., 2012).

The involvement of school counselors in leading career-focused efforts within project-based learning reflects both the potential and the challenge of implementing such initiatives in rural schools. While crucial to the project's success, the participation of school counselors adds to the persistent issue of role overload for school counselors in rural areas (Ault et al., 2024). However, the American School Counselor Association (2019) highlights the importance of school counselors engaging in career development through structured activities such as classroom guidance lessons, individual student planning, and collaboration with community members. This particular project leverages these specific components of the American School Counselor Association (2019), and aided in supporting school counselors as they worked towards integrating career-related content into their STEM PBL lessons. School counselors within this project were provided with ample support through planning time, access to materials, collaboration with their STEM teachers, and consistent coaching sessions to ensure their success.

Project-based learning

Project-based learning is a student-centered instructional strategy that places students into collaborative groups to investigate real-world problems by producing authentic products (Krajcik et al., 2008; Thomas, 2000). PBL, when well designed and aligned with current national standards (NGSS Lead States, 2013; Common Core Standards, 2010), can engage students in science and mathematics practices to learn academic content (Bielek et al., 2022; Huang and DosAlmas, 2024). Scholars have highlighted the impact of PBL on students' engagement, academic achievement, and 21st-century skills, such as critical thinking, collaboration, and creative problem-solving (Chen and Yang, 2019; Hasni et al., 2016; Kokotsaki et al., 2016; Thomas, 2000). More recently, Huang (2023) reviewed 47 PBL research studies, with 31 focused on STEM content, published since 2019 to understand the effectiveness of PBL in high school educational settings. Huang (2023) found support for PBL to increase student interest, collaboration, and content knowledge, especially in STEM, but stated that student factors such as students' content knowledge and technology skills can impact project success.

Within the PBL literature, authors describe the importance of teacher preparation, motivation, and student guidance on the effectiveness of PBL with secondary students (Blumenfeld, 1994; Huang, 2023; Lotter et al., 2019). Studies of teachers' enactment of PBL curriculum at the middle school level has centered mostly on students in larger urban districts (e.g., Capraro et al., 2016; Krajcik et al., 2008) with fewer studies situated in rural schools (e.g., Carrabba and Farmer, 2018; Chen and Lin, 2019). Teachers often struggle with implementing student-centered inquiry practices, managing student collaboration, obtaining resources, and time management (Viro et al., 2020) and require in-depth support through multiple-year professional development programs for effective implementations (Falik et al., 2008; Juuti et al., 2021; Mentzer et al., 2017).

Engaging secondary school students in PBL units focused on local environmental or community issues has been shown to increase student engagement and confidence in their ability to do science as well as increase their connection to their local community (Basche et al., 2016; Casapulla and Hess, 2022). Benavides et al. (2023) described the power of engaging middle school girls in STEM PBL units in which they designed authentic products using community members' ideas and environmental sustainability principles to solve local community problems. Alternatively, Squire et al. (2003) found in a case study of four teachers enacting PBL units in rural schools that when the units failed to connect the larger science ideas to local issues, they were less engaging for students.

Place-based education (PBE) in rural schools

As previously stated, PBE is an educational approach that emphasizes learning rooted in what is local–the history, environment, culture, and economy of a particular place (Gruenewald and Smith, 2008; Sobel, 2004). While Smith and Sobel (2010) worry that a misconception of PBE (often referred to as community-based education) is that it is only for rural schools, these schools are "tightly linked to their communities" (Theobald and Nachtigal, 1995, p. 132), and PBE can inherently be connected to these educational settings. Shamah and MacTavish (2009) elaborate that place-based knowledge can benefit rural youth through engagement with nature, a social connection to multiple generations, and understanding how the land around them can be used for natural resources. Smith and Sobel (2010) explain that students benefit from the knowledge and skills of community members and an increase in an emotional connection to the content that probes them to continue learning outside of the classroom. They also provide data describing the benefit of a "whole citizens" (p. 102) approach to the community where this PBE is situated, noting that "all stakeholders in the educational endeavor–students, teachers, and the communities that support them–benefit" (p. 101). In light of PBE's demonstrated impact on rural communities, studies have shown that specific elements within PBE enhance student learning and community engagement (Smith and Sobel, 2010).

Although there are many elements of PBE defined in the literature, this paper will focus on four common ones in the literature. An important beneficial element of PBE is a focus on community partnerships and engagement. Smith and Sobel (2010) explore how schools can utilize local environments and community resources. These partnerships enhance both the academic achievement of students and community health. Theobald and Nachtigal (1995) describe the importance of community in PBE in contributing to the recreation of a community and the renewal of schools by making learning experiential, allowing students to understand their roles in the world. This idea leads us to another element of PBE: experiential learning. Sobel (2004) outlines various case studies where experiential learning is relevant in PBE through outdoor and community activities. This experiential learning enhanced student engagement and learning outcomes, especially when paired with environmental stewardship/sustainability (Kudryastev et al., 2012), our next element of PBE. Powers (2004) evaluated PBE programs and detailed the role of hands-on environmental science projects in fostering students' connection with local ecosystems, an increase in student engagement, and a notable increase in students' performance in special education. Ballard et al. (2017) explained that integrating environmental stewardship within PBE allowed students to foster a commitment to environmental stewardship and conservation. The last element of PBE to be presented is interdisciplinary learning, an essential part of PBE that highlights many other elements. PBE utilizes interdisciplinary or cross-curriculum content connections to foster a deeper understanding of place (Gruenewald, 2003). For example, Ernst and Monroe (2004) explored how this interdisciplinary education enhanced students' critical thinking skills across different subject areas.

Methods

We utilized a descriptive multiple-case design approach with cross-case analysis, with the middle school team's PBL implementation within the context of the AWAKE-STEM PD program being the unit of study (Creswell, 2014; Priya, 2021). A descriptive case study is used to describe a phenomenon in a real-world context, especially when the boundaries between the phenomenon and context are not clearly evident (Yin, 2014). In this study, the phenomenon of interest was the implementation of community- and career-connected PBL units in rural middle schools, shaped by both the school environment and the PD intervention.

We selected a multiple-case design to examine the implementation of PBL units across three different rural school teams. This design strengthens the rigor and credibility of the findings by allowing for cross-case comparisons that highlight both unique and shared experiences across cases (Priya, 2021; Yin, 2014). Unlike a single case study, a multiple-case design offers more robust and compelling insights and helps to minimize the influence of researcher bias or data collection errors by providing triangulated evidence from multiple contexts. Within this framework, we also conducted cross-case analysis, detailed further in this section, to synthesize insights and draw broader conclusions about the implementation across rural schools.

Participants and rural schools

Data were collected from several teams during the first year of a federally funded grant project. Our case study focuses on three educator teams from rural schools (pseudonyms): Horizon Middle School (HMS), Evergreen Middle School (EMS), and Titan Middle School (TMS). Table 2 provides additional demographics on the schools and students attending the schools.

HMS

The team from HMS consisted of a fifth-grade general education teacher (Kendra, Black female), a teaching assistant (Victor, Black male), an instructional coach (Rita, Black female), and a school counselor (Susan, Black female). HMS is categorized as a rural distant (NCES school locale 42) PK-8th grade school. HMS is a Title 1 school designated as an "Underperforming School" in 2023 and assigned a continuous improvement/ turnaround plan from the state Department of Education. They have since raised their score and are no longer classified as underperforming. Kendra, who has a master's degree and is currently enrolled in an education doctoral program, has 11 years of teaching experience with 6 years at HMS. Victor, who was working as an uncertified teaching assistant at the time of the unit implementation, has been in education for 4 years, with 3 years at HMS, and has a bachelor's degree. Rita, the instructional coach, is a certified K-6 teacher with 7 years of classroom experience. She has been a literacy coach at HMS for 6 years. Susan has been in education for 23 years but has spent the last 13 years at HMS.

EMS

The team from EMS consisted of a sixth-grade mathematics/ science teacher (Emma, Black Female), a sixth-grade science teacher (White female), and a school counselor (Wendy, White female). At the time of enrollment in the program, EMS was categorized as a rural fringe (NCES school locale 41) 6th-8th grade school with approximately 616 students enrolled. The two teachers on the team implemented the unit separately with their students, but students came together as a large group for the community partner presentations. This case study focuses on Emma's implementation of the unit with a sixth-grade mathematics class and her collaboration with Wendy, the school counselor. Emma had a Bachelor's degree and had been teaching for 7 years, with 2 years at EMS. Wendy had a master's degree and was in her second year working as a school counselor at EMS, having changed careers after working as a licensed counselor outside of education.

TMS

Finally, the team from TMS consisted of a seventh-grade ELA/ STEM teacher (Rachel, Black female), a seventh-grade science/STEM teacher (Alyssa, Black female), and a school counselor (Amy, Black female). TMS is categorized as a rural fringe 7th- 8th grade school. Alyssa has a master's degree and 17 years of teaching experience, all at TMS. Rachel has a master's degree and 22 years of teaching experience, with 7 years at TMS. Amy has a bachelor's degree and has been a school counselor for all her 7 years of educational experience at TMS.

AWAKE-STEM professional development program

The PD program, initiated in the Fall of 2023, represents the first year of an updated model based on an established framework previously funded through a state grant. This iteration was structured over the entire year, was virtual other than a one-day orientation in the Fall of 2023 and a three-day institute in the Summer of 2024. The virtual PD included three 8-week graduate-level PBL courses (one Fall 2023, two Spring 2024), earning the teachers a state-level PBL endorsement (Stevens, 2015) and nine graduate credits. The courses allowed the teams to learn key PBL design elements, collaborate to

TABLE 2 Rural school demographics.

School	Team makeup	Categorization	Number of students	Student demographics	Students eligible for free/ reduced lunch
HMS	Fifth-grade general education teacher (Black female); teaching assistant (Black male); instructional coach (Black female); School counselor (Black female)	Rural Distant; PK-8th	130	47% Black, 27% Hispanic, 21% White, 4% two or more races	100%
EMS	Sixth-grade science teacher (White female); sixth-grade math/science teacher (Black female); School counselor (White female)	Rural Fringe; 6th-8th	616	70% Black, 1.5% Hispanic, 7% White, 21.5% two or more races	100%
TMS	Seventh-grade ELA/STEM teacher (Black female); seventh-grade science/STEM teacher (Black female); School counselor (Black female)	Rural Fringe; 7th-8th	350	85% Black, 3.5% Hispanic, 9% White, 2.5% two or more races	100%

Source: U.S. Department of Education, National Center for Education Statistics (2023).

create and implement two PBL units and reflect on their learning and instruction. The team structure was designed to facilitate communication across teacher and school counselor roles and provide opportunities for shared collaboration and expertise (Irvin et al., 2019). For example, the school counselors facilitated opportunities to engage with a spectrum of careers in local STEM career industries related to the PBL topics and standards, primarily through targeted career lessons. Additionally, to enhance community partnerships and industry connections participants were taught how to utilize asset mapping to identify potential partners and we partnered with regional career specialists who helped us identify industry and community partners in our participants' communities. We also provided participants opportunities to share their ideas related to community partnership building in discussion posts in the first and second course. During the summer institute, teachers were able to reevaluate their units based on what they learned and continue to use authentic gold standard PBL, PBE, and STEM career connections to improve their PBL units for implementation in year 2 of the program.

To support sustainable practices, the program included ongoing Cognitive Coaching™ (Costa and Garmston, 2002) in which trained project mentors supported the teams' instructional journeys (Mentzer et al., 2017). The Cognitive Coaching™ course for project mentors encompassed eight 7-h training sessions, spanning a total of 56 training hours across 6 months. Project mentors, also referred to as Cognitive Coaches™ in this capacity, corresponded with team members via email on a weekly basis as necessary to coordinate Cognitive Coaching™ meetings; teams opted to meet with their Cognitive Coaches at least once a month, typically every other week or every 3 weeks based on their identified needs. Cognitive Coaching™ consisted of brainstorming and supporting teams' efforts, as well as providing constructive feedback on their instructional methods surrounding PBL from video observations via SeeMeTeach software (Berg et al., 2023). School team members would review comments, which include time stamp indicators embedded in the videos, with Cognitive Coaches in real time to expand on critical feedback and concurrently review instructional demonstrations.

Moreover, the model was designed to foster a Virtual Professional Learning Community (VPLC) that extended beyond the immediate duration of the grant, aiming to continue participant engagement and support through professional development activities and shared resources. In year 2, the VPLC includes monthly structured synchronous online meetings and monthly discussion posts via an online learning platform. Additionally, the program offered incentives for voluntary participation: each educator received an individual stipend, as well as compensation for travel and lodging for non-virtual events. The team also received a classroom materials stipend. The comprehensive support aimed not only to alleviate logistical burdens associated with professional development but also to underscore the commitment to enhancing PBL practices in rural settings.

Data sources

Utilizing the multiple-case study approach with cross-case analysis, the middle school team's PBL implementation in the context of the AWAKE-STEM PD program was the unit of study (Creswell, 2014; Priya, 2021). The three teams that were the focus of this study were purposefully sampled from the pool of eight available teams in their cohort based on the completeness of the data sources (e.g., video recordings, interviews, and journals) to answer the research questions reliably (Priya, 2021).

Recorded observations and 6A's + C rubric

Recorded observations of the team's instruction in the classroom were the primary data source for this study. Each teacher or school counselor recorded at least one class's PBL unit implementation using an iPad/Swivl. Recordings from the team's second PBL unit, implemented in Spring 2024, were used for the case study. At HMS, 10 lessons were recorded in Kendra's fifth-grade general education class, with other educators in a co-teaching role. At EMS, recordings were taken in Emma's sixth-grade science/ mathematics class during an 11-day PBL implementation. At TMS, 10 lessons were recorded in Alyssa's seventh-grade science class and two in Rachel's seventh-grade ELA class during the 11-day PBL implementation. We adapted the PBL Works 6 A's rubric from a 3-point to a 4-point scale (0 = not evident, 1 = emerging, 2 = approaching proficient, 3 = proficient, 4 = exceeds) and added a career connections indicator to further align with our project goals of having teachers and school counselors collaborate to develop STEM-focused PBL units that integrated career and community connections.

Reflection journals and interviews

Educators composed three 2–4 page, double-spaced, reflective journals about their implementation of PBL units during the third PBL course, covering the six PBL design elements. They also wrote one journal about their team's collaboration. Semi-structured interviews were conducted at the start and end of the school year to explore beliefs about PBL implementation, team collaboration, and the impact of STEM careers and community connections. The interviews lasted 30–45 min and were conducted via Zoom or face-to-face.

Data analysis

As previously described, we utilized a descriptive multiple-case study design with cross-case analysis to investigate how three different rural educator teams implemented their PBL units within the context of the AWAKE-STEM PD program. Following the design guidance of Yin (2014), each team's implementation was first treated as a bounded case and analyzed individually to understand the nuances of their local implementation, then compared across cases to identify patterns and contrasts.

Individual case analysis

Each team's recorded observations, reflective journals and interviews were analyzed independently to build a rich case description (Creswell, 2014; Yin, 2014). For each case, all recorded observations were uploaded to SeeMeTeach (Berg et al., 2023), and a team of four researchers qualitatively coded them using *a priori* codes that were created and agreed upon as a research group. The a priori codes were based on teacher actions, student actions, and PBL/PBE design elements. There were 16 codes specific to teacher actions, including instructional strategies, lesson flow/pace, learning environment, and behavior management, to name a few. Instructional strategies refer to the methods demonstrated for facilitating instruction, such as laboratory activities. Lesson flow and pace address factors that influence the progression or timing of a lesson. Items coded under the learning environment involved a general assessment of the classroom atmosphere every 10 min of the recording. This category included aspects such as class culture, a respectful environment that fosters learning and idea-sharing (or its absence), and physical changes to the learning space. Lastly, behavior management captures moments when the teacher addresses student behavior, focusing on positive or negative actions. Similarly, there were 16 distinct codes for students' actions, including voice/choice, place/community, critique and revision, and authenticity. The code voice/choice refers to students' agency within the PBL process. Voice reflects students' input on what is valued or important, while choice involves their role in shaping or driving their work during a project. Elements coded as place/community highlight the integration of learning within a specific context, such as the connections to global, national, or local settings. Critique and revision capture instances where students receive feedback and have opportunities to refine their work. Finally, authenticity codes emphasize real-world, recognizable scenarios or circumstances that students find relatable, including using disciplinary (STEM) tools as professionals might employ them.

Four videos were selected to represent key PBL components: entry event, sustained inquiry, community partnerships/career, and public product. The research team coded the first video for each team collectively, followed by pairs coding the remaining videos. The entire team met weekly to review and reach a consensus on the codes. Two researchers also applied the 6 A's + C rubric to each unit, reaching 100% agreement on rubric scores.

Journals (J1, J2, J3, J4) were analyzed qualitatively for statements on PBL design strengths and weaknesses, community and STEM career connections, and student learning (Saldana, 2016). Interview (pre and post) transcripts were similarly coded using the journal codes and open-coded for emerging themes. Quotes from journals and interviews were used to support and validate findings from the video analysis, addressing the research questions. This allowed for within-case triangulation of data sources to support or challenge emergent themes.

Cross-case analysis

After completing individual case analyses, we conducted a cross-case analysis to explore shared and divergent patterns among the teams. Following the guidance of Huberman and Miles (2002), we employed multiple tactics for cross-case comparison. First, we examined the implementation of the 6 A's + C rubric scores across teams to identify common areas of strength and areas needing support, such as applied learning and adult connections. Next, we analyzed themes from the journals and interviews across cases, searching for both within-group similarities and intergroup differences, particularly regarding community partnerships, career integration, and interdisciplinary teaching practices.

Google Sheets was utilized to display data and visual themes, and patterns, enabling structured comparison across teams. For example, we compared how each team integrated STEM careers into their units, what type of community partners were utilized, and the challenges that were encountered. We also examined how differences in the rural context and the team's composition may have shaped each team's approach to implementation. By layering individual case findings with cross-case comparisons, we constructed an analytically robust interpretation of how place-based and STEM career-focused PBL was implemented in three distinct rural school contexts.

Results

The results of this study highlight key themes in educator teams' experiences with PBL, collaboration, and community engagement. Before participation in the AWAKE-STEM program, the educators engaged in limited interdisciplinary collaboration and minimal community involvement s. While some teachers had prior exposure to PBL, their approaches were often isolated, lacking coordination across disciplines or external partnerships. During PBL implementation through the AWAKE-STEM program, teams demonstrated strengths in Active Exploration and Career Connections, but encountered difficulties fully integrating Authenticity, Applied Learning, and Adult Connections. Despite some obstacles, educator teams recognized the value of interdisciplinary instruction, incorporating STEM career exploration, technology integration, and collaboration with local industry professionals. Community experts played a crucial role in providing real-world insights, though sustained engagement remained a challenge. The following sections further examine these themes, offering insights into how educator teams navigated challenges, implemented strategies, and identified opportunities for growth.

Collaboration and PBL use before PD

Before they began teaching their first PBL, the educators were all interviewed about their prior experience with project-based learning and how they engaged students with community and career connections before participating in the program.

Individual case analysis: collaboration and PBL at HMS

Before the AWAKE-STEM program started, Kendra described using PBL in her classroom but not collaborating with others outside of her classroom. As a small rural school, Kendra explained that there is only one classroom teacher per grade level. Kendra had been supported by Victor, a STEM-focused teaching assistant, who also described a lack of collaboration outside the classroom. Although Kendra had Susan in her classroom describing careers, "especially during career week," (pre) career collaboration was limited beyond those instances. Similarly, although Kendra had a strong sense of commitment to her community, she had little community interaction in her classroom before AWAKE-STEM PD, stating, "It's really hard to get people to come to [town]-- it's literally in the woods" (pre). Kendra cited community partners claiming distance to the school as the main deterrent to interaction. Similar to this, Susan reflected in her journals that "scheduling conflicts" led to "limited community involvement" (J3) in their PBL units but still described the overall effectiveness in collaboration "as a 9 out of 10." Having had experience with PBL at a previous school and having HMS be considered a "STEM" school, Kendra felt she was already experienced in PBL. She said, "But I realized I really did not remember how to do it effectively, and I wasn't sure since I have not heard about anyone else around school doing it. I just did not ask anyone" (pre).

Individual case analysis: collaboration and PBL at EMS

Emma, EMS's mathematics teacher, had little experience with PBL instruction before the AWAKE-STEM program, describing her teaching as more traditional. Later in her first journal, after teaching the second PBL unit, Emma stated, "This is the second PBL that I have taught, and while this way of teaching is very different than the traditional style of teaching, our students need authentic ways to learn. It has been a learning process for me as well as them, and with time, I will become even better." Similarly, the school counselor, Wendy, described having no prior understanding of PBL except remembering a past teacher who taught through projects. She also had limited interaction with students in some science and mathematics classrooms, describing how school counselors were "not allowed to go into…the more rigorous academic classes..." However, Emma described how she had not engaged students with the community before the professional development program, and students' only career instruction in her class was "using our counselor to come in and talk with students about the different careers." Outside of monthly classroom career-focused or guidance lessons, Wendy described bringing in some community members for "lunch and learns" with students before the AWAKE-STEM program, but she did not collaborate with teachers as the school counselor.

Individual case analysis: collaboration and PBL at TMS

Rachel, the ELA/STEM teacher, described her team as a "nice fit" (pre) for the AWAKE-STEM program due to their consistent collaboration with the science teacher, Alyssa, and Amy, school counselor. Alyssa underscored Rachel's dedication to interdisciplinary work:

> Once she [Rachel] would find out which topics we are gonna be teaching, she would find a novel that's connected to that…So our team could operate... along the lines of being interdisciplinary. So students could realize... how we are connected (pre).

Although Alyssa noted limited direct collaboration with Amy, the school counselor, she acknowledged Amy's value in fostering connections: "She knows contacts, or she knows people who... get you… connected with that person" (pre). Reflecting on her prior experiences with project-based learning, Alyssa shared a failed attempt to implement PBL:

> We had a three-day PD, and so, of course, comparing that to our experience right now, that was a rush job type deal. And I cannot say I always had the desire to actually implement it. And I recall even our STEM team and the 8th-grade STEM team getting together to... and it just... fell through (pre).

Although not specific to her classroom instruction or personal involvement, Rachel indicated that "a lot of the events that we do have with the school, it is connected to community involvement" (pre). Alyssa reflected on her initial unfamiliarity with the local community when she started teaching at TMS 15 years ago and the importance of building relationships over time. She shared,

> When they [students] see you out at those things, you know, they realize, hold on, you came out, you are interested in... what we are doing or... things that were happening in the community. So it really helps. It says you are a person outside of the classroom (pre).

PBL Unit Implementation

RQ1: *How do the educator teams' implementations of PBL units reflect key PBL design elements in rural settings?*

Using the PBL 6 A's + C implementation rubric and video observations, each team's PBL unit implementation was evaluated on how effectively they implemented the six A's (Steinberg, 1998) and career connections while teaching their PBL unit with one class of students. With a max score of 28, the team's scores were as follows: EMS scored 18 points with scores in the 2–3 range for the different indicators, HMS scored 20 points ranging from 2 to 4 points, and TMS scored 15 with scores ranging from 2 to 3 per indicator. The goal for the PBL unit was a proficient level (3) score for all indicators in the first year of the AWAKE-STEM PD program. Table 3 provides a breakdown of scores by indicator for each team with supporting evidence from observations.

Individual case analysis: HMS implementation

Horizon Middle School scored approaching proficient (2) for Applied Learning and Assessment Practices. This team focused on solving the problem of their school being located in a food desert by creating a community garden at their school and focusing on healthy eating and exercise. Applied learning scored less than proficient for HMS as the teacher team assigned students their project focus areas, such as disease and diet, which limited student-driven inquiry. Students applied their new knowledge of gardening and healthy eating to the creation of their gardens and healthy lifestyle final presentations. Assessment was primarily formative during class time (teacher questions, short group activities such as a farm-to-table card sort), and students made limited revisions to their final products. Kendra noted, "Other than participating in the discussion, students were not held accountable for usage of structured journals to log their progress or revise their thinking" (J2). Instead of a community health fair, which was proposed as the final public event in the unit plan, the students presented posters on their topics in front of their created school garden to another grade level.

The HMS educators scored proficient (level 3) on the PBL rubric for Adult Connections, Authenticity, Academic Rigor, and STEM Career Connections. Students interacted regularly with community members, most related to STEM careers, despite initial challenges in building these connections. Kendra reflected that "engaging with community partners can not only enhance my understanding of community needs and assets but also enrich my teaching practice with authentic, relevant experiences for my students" (J4). These connections included input from community partners, such as the regional STEM coach, who reminded students that although the "gardening PBL has fun, real-world experiences that they learned from, they had to remember that academics and learning is at the core of it all" (Kendra, J3). Victor described difficulties finding local community partners, stating that:

> …outside of the farmers, we really had to go outside of the area, in a sense, but we had to pull people from different areas, which

TABLE 3 PBL unit design elements rubric scores and justification.

Design element	HMS	EMS	TMS
Academic rigor	Rubric Score: 3 DQ: How can our school work together to create a sustainable garden for our community that addresses the challenges of limited resources? Standards Health and Safety Education: N-5.5.3 Explore the advantages of using fresh foods and produce. N-5.8.1 Encourage peers, family, and others to choose healthy foods and be physically active. N-6.1.4 Differentiate between unhealthy and healthy foods, snacks, and beverages. Science: 5-PS1-3. Make observations and measurements to identify materials based on their properties. 5-LS1-1. Support an argument with evidence that plants obtain materials for growth mainly from air and water. 5-ESS3-1. Evaluate potential solutions to problems that individual communities face in protecting the Earth's resources and environment. 6-ESS1-4. Develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity.	Rubric Score: 3 DQ: How can we create or improve our current community parks to make them more inclusive while using as many community resources as possible? Standards: Science: 6-ESS2-1 Develop a model to describe the cycling of Earth's materials and the flow of energy that drives this process. Math: 6.DS.1: Differentiate between statistical and non-statistical questions; 6.DS.4: Select and create an appropriate display for numerical data, including dot plots, histograms, and box plots.	Rubric Score: 3 DQ: How can we plan/create/build a (solutions) model to conserve groundwater resources that positively impact the health of people and natural resources? Standards: Science: 7-ESS3-1. Construct a scientific explanation based on evidence for how the uneven distributions of Earth's mineral, energy, and groundwater resources result from past and current geoscience processes. 7-ESS3-3. Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment. Reading: Informational Text Standard 12: Read independently and comprehend a variety of texts for the purposes of reading for enjoyment, acquiring new learning, and building stamina; reflect on and respond to increasingly complex text over time. 12.1 Engage in whole and small group reading with purpose and understanding. 12.3 Read and respond according to task and purpose to become self-directed, critical readers and thinkers.
Active exploration	Rubric Score: 4 Students created a school garden with help from community partners (local farmers), field experts (physical education teacher), and other online sources. Students ask need-to-know questions and answer them throughout the unit.	Rubric Score: 3 Students researched local parks and recreation websites for features they could add to local parks; evaluated local parks data; asked local Mayor questions; created a survey that was not sent out to the public; created a survey and 3D models	Rubric Score: 2 Students and teachers frequently mentioned the field trip to local water treatment plants. Students read a community-focused article on water quality, conducted mostly online research, engaged minimally with science tools (one PhET simulation, an online soil lab), and discussed but did not record local water testing.
Authenticity	Rubric Score: 3 Students engaged with local community issues to create a garden and recipes to share with the community. Student teams presented posters in front of the garden based on their area of focus: exercise, nutrition, garden vegetables, disease prevention from healthy eating.	Rubric Score: 2 Simulated "real world" activities by designing new park features based on student and community needs; the Mayor spoke to students about similar local park projects; Students presented final posters or Tinkercad models to other students	Rubric Score: 2 Students addressed local water conservation by designing rain barrels in Tinkercad and creating infographics. They visited water treatment plants but had no public presentations. Budgets were drafted for potential school runoff and garden solutions, but plans remained early.
Applied learning	Rubric Score: 2 Students were assigned a specific aspect of what they were addressing for the community. Community partners were not present for the presentation. Students applied new knowledge of gardening and healthy eating to create final project.	Rubric Score: 2 Students worked in teams to create park models with features of interest to them based on local needs; students learned about statistical and non-statistical questions and created a park survey (but did not give it to community members); students completed park feature budget; students created draft and final models, little critique and revision except from teacher	Rubric Score: 2 Students formed self-selected teams to design a Tinkercad model addressing a local water conservation issue, primarily rain barrels. They reflected on team collaboration, but no external adults provided critique, and models or infographics were not publicly presented.

(Continued)

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TABLE 3 (Continued)

Design element	HMS	EMS	TMS
Assessment practices	Rubric Score: 2 Students have an ongoing process of creating and planting for the garden; assessment is formative during in-class time.	Rubric Score: 3 Students receive frequent feedback from teacher with Google documents; the Mayor provides general feedback to students early in the process; the project includes a budget and model of the park (2D or 3D)	Rubric Score: 2 Students analyze the DQ in ELA post-field trips, while science content is taught separately and tested before the final product. Formative assessments focus on water conservation, and students create an infographic on water solutions. Feedback is limited to the teacher, and no project rubric has been discussed.
Adult connections	Rubric Score: 3 Students interact with multiple adults throughout the unit (PE/ health educator, cafeteria workers, local chef, local farmers, personal trainer) and work with them to learn content and create their final products; the final presentation had only school personnel and no community members as part of the public audience.	Rubric Score: 2 Students interact with the local Mayor as a guest speaker; feedback is limited to question and answer sessions; no public audience for final presentations.	Rubric Score: 2 Students visit drinking and wastewater plants and hear from water industry professionals but receive no further expert interaction or feedback. Final presentations lack a public audience.
STEM career connections	Rubric Score: 3 Various community partners (farmers, PE/ health teacher) speak to students and help them to create their garden. Students learn about land surveyors, arborists, nursing, and personal training careers.	Rubric Score: 3 School counselor taught lesson on 3 STEM careers associated with creating local parks: architect, plumber, and civil engineer; teacher pointed out careers on the local parks and recreation website and integrated careers throughout; students designed survey and 3D models using Tinkercad program.	Rubric Score: 2 Students explored water treatment careers through a field trip, a school counselor-led STEM career lesson, and a hands-on project simulating professional skills by designing a Tinkercad model and budgeting ($100 or less) for a school rain barrel.
Total score	20/28	18/28	15/28

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> was not a problem at all, from different counties, different cities to come in and assist us (post).

Kendra described a "backwards approach" (post) in learning about careers by involving students in work and then having them determine what careers related to that work. To her, this approach contributed to a more authentic and rigorous unit. Susan describes her own benefit from the engagement with community partners as having "enriched my teaching practice by providing authentic, relevant experiences for my students" (J4). The instructional coach, too, highlighted "that those community members felt valued in being brought in" (post). The team's second unit STEM career connections and adult connections did not earn a four due to the lack of students working alongside adults in the community outside of the school at relevant worksites and the lack of adults critiquing and offering feedback on their final projects.

The team scored exceeds (4) for Active Exploration as students frequently engaged in field-based activities, gathering information from diverse sources, including community experts. They began by reading a novel, Seedfolks, about a community garden, and Kendra prompted them with questions like "How did Ana feel when she uncovered the White bean seeds?" and "What do you think prompted her to care about the bean seeds?" (J1). Despite earning a four on Active Exploration, Kendra reflected on this conversation with students after the entry event. She believed she could have furthered active exploration by focusing the lesson on a question like "Do you think Ana would've agreed with what was being planted?" (J1). Students then continued with active exploration by creating need-to-know questions, learning to plant a garden, and finally understanding local struggles with healthy eating, developing healthy food solutions, and creating recipes aligned with foods grown in their garden. Susan reflected on a missed opportunity of having "students interact with food choices" by participating in "taste tests to experience firsthand the differences between healthy and unhealthy foods" (J2). Despite this, Rita, the instructional coach described the students as "self-motivated" and "determined" because this PBL allowed them to "do different things" (post).

Individual case analysis: EMS implementation

EMS scored approaching proficient (2) for Authenticity, Adult Connections, and Applied Learning. For Authenticity, the project centered around students identifying features of local parks that were missing from the area based on their interests and community needs. Students researched the local parks and recreation website and developed a survey that could have been used to gather data from community members on what park features were needed. The mayor of a nearby town, which had recently passed a local penny tax to support developing parks, spoke to all the students, helping them to think through logistical issues with park development (such as where to put the park, how to pay for it, how to justify the park as a community resource, etc.) and to provide realistic information on park development costs. Emma described in her first journal how the mayor "was also able to give them insight on if a feature they thought of would not be sustainable for the area." The students designed and developed electronic or hand-drawn park models or features (e.g., a wheelchair-accessible swing). Students had a choice in how they designed their models, with some using Tinkercad (an electronic modeling software) they had learned in their STEM class. Students also had to develop a materials list for at least one main park feature, including identifying "where these resources were sourced from using the rock cycle" (Emma, J1) and a budget for the local cost of materials for that park feature. For example, Emma described how "some students that were thinking about the size of their dog park and talking about what features would be important… This was done by students researching fencing and how much it cost" (J2). Although the problem of creating new features for local parks was relevant, the project lacked some authenticity– students did not send out the surveys they created to community members and only presented their final products to their peers in class and not an authentic external audience. Adult connections beyond the teachers and school counselor were limited to an early visit from the Mayor, who provided initial feedback on project ideas. For applied learning, the students' park models shifted toward artistic drawings rather than scientific or mathematical models, putting less emphasis on the science and mathematics standards in the final product. Emma noted, "[Students] were not connecting why they needed to find where their products for their features were being sourced from. This lack of connection made it hard for them to connect the [science] academic standards to the context of the project" (J1). Student collaboration was mainly confined to the final project stages, with students working individually during initial research. Emma described that:

> Students were working in groups after they came up with ideas individually that they wanted to add to the local parks. Some of the groups that collaborated together had the same idea while other groups were together and had different features that they would add together. The students had to give each other feedback and combine their ideas to make the final product better (J2).

Academic Rigor, Active Exploration, Assessment, and STEM Career Connections were scored proficient (3). Students applied their understanding of mathematics standards, using real-world technology tools (e.g., survey tools, databases, 3D modeling software) to draw scale models, analyze parks and recreation data to drive park construction, and develop a budget for materials. Emma was seen providing daily formative feedback through questioning and monitoring student progress as they researched and worked on their models. She described how students "were able to type their information on a document that I created for them and record their findings." and how she would improve her assessment in the future by providing a document "for each activity to guide their thought processes" (J3).

During the unit, Wendy, the school counselor, taught a lesson on three STEM careers associated with creating local parks: architect, plumber, and civil engineer. She described the importance of teaching students about careers with different educational requirements:

> So I'm a true believer that, like all careers are important…letting the kids know that if you want to go to college, that's great. If you want to go to a technical school, that's great. If you wanna just get out of high school and just go into training, then that's great too (post).

During several lessons, Emma also pointed out relevant careers on the local parks and recreation website and integrated careers throughout the unit with videos and student-written responses in handouts.

Individual case analysis: TMS implementation

TMS scored approaching proficient (2) for Active Exploration, Authenticity, Applied Learning, Assessment Practices, and Adult Connections. Although the problem of conserving groundwater to impact health and natural resources positively was a relevant and authentic topic to be explored, the students' active exploration was limited to viewing and reading about local water and wastewater treatment plants rather than engaging in the tools related to them. For example, students visited their local water and wastewater treatment plants but did not engage in testing their local water samples. Amy, the school counselor, spoke to the level of authenticity, suggesting that "instead of merely visiting the treatment plants, students were tasked with investigating a specific topic or issue related to the water treatment plants, encouraging them to ask questions, gather information, and draw conclusions" (J1) as they tried to provide a solution to a water distribution issue (flooding in one area and a need to move water to a proposed school garden area) on their school grounds. To this point, Alyssa acknowledged an opportunity for growth surrounding data collection:

> They [students] researched ideas for designing their rain catchers and recorded the costs of materials required for this project, but I do not think that counts as data collection. If my team chooses this unit plan for the next school year, students could collect data on water usage in [masked] county (J2).

Applied learning was, again, limited as students were guided to choosing to create a rain barrel, despite some groups talking about showers or other items to design. Alyssa reflected, "We intended for our students to build a physical rain catcher but modified our plans due to budget constraints" (J2). Students were then instructed to compose infographic posters "with their own research" (J2), highlighting five suggestions on in-home water conservation. Alyssa encouraged students to share these materials with family and community members, acknowledging this as "a real opportunity for our students to make a difference in their community" (J1). While adults were present at the entry event, which included the field trips to the local water treatment plants, adult community members were not present to critique and give feedback on students' plans later in the unit. Alyssa reflected on a growth opportunity moving forward," to ask our community partners upfront if they are available to participate throughout the unit and for the presentation at the end" (J3). Students were assessed formatively throughout the unit with Kahoot and Quizlets. Rachel also spoke about her utilization of a reflection and revision process as a form of student assessment:

> Learners have used KWL charts to progress monitor, respond, and reflect before and during tasks while building connections to various milestones in the PBL. Learning logs are also used at various milestones to reflect, evaluative measures, and avenues to kickstart next steps (J3).

Academic Rigor and STEM Career Connections were scored as approaching proficient (2). Through traditional instruction and interactive activities, students engaged with their content standards in both ELA and science classes. In ELA, students analyzed the DQ and annotated an article about a local water quality issue. Science instruction incorporated assessments such as Kahoot quizzes and written student responses to questions after engaging with videos or online simulations. However, the content instruction was mostly separated from the product design as students took a content test before they were introduced to the rain catcher design project. Although students explored various STEM careers through their trip to the two water treatment facilities and a lesson focused on water-related careers and soft skills, career instruction was not integrated throughout the unit. Some students utilized STEM professional's tools by using Tinkercad to design their rain catcher models while others created hand drawn models. Students did create product budgets researching local costs to potentially bring a rain catcher system to their school the following year; however, other opportunities to apply expert skills to solving the driving question were limited.

PBL implementation summary

Thus, the three teams showed varied implementation of the PBL design elements within their second unit plan. Each team showed differing strengths and weaknesses with engaging students in the PBL elements; however, they all reflected on how they could further improve each area in their journals for their second year implementation.

Cross-case analysis of research question 2

RQ2: In what ways do the educator teams integrate local community assets and STEM career opportunities into their rural place-based PBL units?

The place-based elements described in the literature review (Gruenewald, 2003; Smith and Sobel, 2010) that were most prominent in our team's PBL units included an emphasis on community improvement and natural resources, the inclusion of community-based experts, and an interdisciplinary content focus.

Community improvement and natural resources

All teams focused their units on improving their local community, with HMS and EMS focusing their driving questions solely on how they could solve a community issue. At HMS, the students created a school-based garden that the community could use as a local healthy food source. The students also created healthy recipes to share with the community using produce they grew, as this school was in a food desert (Karpyn et al., 2019). Kendra described how the entire school and community got involved in the garden, "so I feel like PBL did not affect my classroom, it affected our school and our community as a whole because it started with just my class, but then everyone was involved. It became everyone's project" (post). EMS focused on adding a new recreation feature or creating a community park to serve the students' interests and the community's needs. Students researched the local parks and recreation website and data provided by a local park staff member to learn about current park features. They focused not only on their wants and needs for their park features but also strived to make the features more inclusive for all community members. Wendy, the school counselor from EMS, described students' interest due to addressing features missing from their town parks:

> …we had our town mayor come in because we had a penny tax, and then they were actually putting the money into parks in our community. And a lot of our kids frequent those parks, whether it's for sports or just regular recreation. So, having them be able to come up with their own design that you know, if we were building the park and it was our choice, these are the things that are important to us to put in the park (post).

Although TMS's driving question did not focus on their local community, students created local water conservation solutions focused on better ways to use rainwater that often flooded a field on their school property. Rachel emphasized the importance of strong community partnerships in ensuring meaningful PBL experiences, stating, "Securing and communicating with the community to build partnerships is needed to ensure all components [of PBL] are executed for more enduring understandings" (J1). She highlighted how her team initially sought to deepen student engagement by refining their DQ before a field trip to their local water and wastewater treatment plants. However, due to a scheduling conflict, the field trip was moved earlier in the unit. Rachel reflected on the students' adaptability, noting that students "were still very prepared and constructed relevant questions for representatives from both sites," adding that the tours provided opportunities to "promote student engagement, fuel our planned lessons and activities in the unit, and connect careers and community partnerships" (J2). Amy echoed this sentiment, underscoring the value of structuring field experiences around purposeful inquiry. She explained that they "were able to frame the exposure and the experience around guiding questions or challenges relevant to the purpose of the field study to both treatment plants," emphasizing that this approach "deepens engagement, encourages active learning, and enhances the overall educational impact of field studies" (J1). Beyond structured learning experiences, Amy also emphasized the team's commitment to intentional community improvement, noting that they "researched the job market trends for our area and surrounding counties" (J4) to align their efforts with local workforce needs. Alyssa stressed the importance of authenticity in PBL, stating, "For students, connecting to an audience can culminate their entire PBL experience, making it authentic and showing them this was not just another typical classroom project" (J3).

Community experts

All the teams initially struggled with finding community partners who could come out to their remote rural schools and interact with their students. Wendy stated, "One struggle that I find is that a lot of people want to be a part of the project; however, due to their work schedule and timing, sometimes this can not happen" (J1). Due to these time limitations, community expert interactions with students were sometimes limited to guest speaker events, such as the mayor session at EMS held in the school media center for all the PBL classes at once. HMS had planned on having many community experts participate in their plan (School Garden and Education Assistance Program, Arbor Day Foundation, nurses, chefs), but due to driving distance and other factors, many did not follow through with their commitment. Despite these limitations, HMS had farming experts interact with their students throughout the unit. A state-level agricultural extension staff member assisted students to build and initially plant appropriate vegetables in their garden. Later in the unit another gardener provided strawberry plants for each student to plant in the garden and taught them about healthy eating from garden products. Finally, the students watched a pre-recorded virtual farm tour. The teams found the most success with engaging experts whose jobs related to educating children, such as community offices with education outreach staff or school personnel, such as the school's physical education teacher and school cafeteria staff to speak about the need for exercise and healthy eating, respectively. Victor described wanting to "vet our people, make sure that we all have a common goal…making sure that they understand what we need…and we understand what they need…making sure we bring in the right people that fits what we need them to do."

The program educators recognized the benefits of involving community experts for content expertise and authentication of local insights. Kendra from HMS appreciated the diverse perspectives: "... all those ideas being able to collaborate was enlightening. I never considered reaching out to the community" (post) and involving them in lesson planning. Similarly, Emma described how she reached out to an expert from their local parks and recreation office, and "she was able to share with me data on the usage as well as provide a map that showed all of the locations of the parks and recreation" (J4) allowing students to make data informed decisions when designing their park features.

When describing changes they wanted to make in their units for next year, the educators often described wanting more community expert engagement throughout the unit. For example, Emma from EMS reflected:

> One of the greatest missed opportunities was lack of community partners providing feedback and students having access to them throughout the process to provide feedback. The student would benefit from having community partners to help guide their thinking as well as the thinking of the teacher. They should play an important role in the planning process to give us feedback and guide the overall plan (J3).

Wendy described learning from having the community expert come too early in the first unit, and that they modified the second unit by "…having the community partner come after we had started the project so students would have questions and have ideas that they would be able to share, this part went very well" (J1).

Rachel acknowledged the initial challenge of identifying relevant careers within the immediate community, noting that many opportunities existed beyond their awareness: "There are so many avenues to connect to careers... I wasn't aware that the wastewater treatment plant was so close to where I lived, and I've been there all my life" (post). She also highlighted the difficulties in establishing partnerships in time to effectively implement lessons, explaining.

> In the local community, like I said, we did the entry events. We were wanting to have a more stable relationship with the business partners, but it was difficult for the first one - trying to find them, work with their schedule, work with ours. But I think

> now we know what to look and ask for upfront. So we were trying to secure those community partnerships (post).

One successful avenue for engaging community experts involved leveraging alum connections, as Amy described, noting that the game wardens who visited were former school students, which helped them easily connect with current students in their first PBL unit. She emphasized the impact of alumni engagement and explained that having alumni return to share their career paths makes the experience more relatable and keeps students engaged. Looking ahead, Amy expressed a desire for community partnerships to be mutually beneficial, recognizing that while industry experts bring valuable knowledge, their effectiveness in an educational setting varies. She pointed out that "they do their job well in the industry that they are in, but they may not be a great speaker" (post), underscoring the importance of ongoing conversations with business partners to ensure educators and industry professionals understand each other's needs.

Interdisciplinary focus

As illustrated in Table 3, all three team's units emphasized at least two different content discipline standards. Emma from EMS collaboratively planned the unit with the science teacher on her team. She taught her students science and mathematics content standards during the park improvement project when students were learning about the rock cycle. She explained that they had to "analyze the information that they were collecting" and "think about the cost associated with the feature" by creating a budget (J1). This approach reinforced the curriculum and introduced real-world applications like budget management. Utilizing tools like Tinkercad, they could integrate the science, math, and design focus and fully incorporate an integrated STEM model. Students at TMS also utilized Tinkercad, adding technology and engineering to design their rain barrels and water transportation solutions.

From TMS, Rachel highlighted the intentionality behind their interdisciplinary collaboration, emphasizing the seamless integration of content areas. She often asked Alyssa for content standards related to their learning. Alyssa affirmed Rachel's commitment to aligning interdisciplinary instruction, adding, "She [Rachel] was definitely going to make sure it aligned with the ELA standards. It was just cool to see how she did that" (post). Amy reflected on the evolving nature of interdisciplinary collaboration, highlighting the role of both teachers and school counselors in strengthening connections between content areas and career readiness. She explained that she offered her perspective as a career specialist in "building those relationships with those business partners, but the teachers were also very helpful and instrumental in helping me to build those relationships because they offered their perspective as a classroom teacher" (post). She further noted the impact of this collaboration on her professional growth, stating, "Collaborating with teachers exposes me to diverse teaching methods and classroom practices. This broadens my understanding of educational approaches and enhances my ability to tailor career guidance strategies" (J4). Looking ahead, Amy expressed her desire to deepen this collaboration, sharing an aspiration to "co-teach during the career session" (J3) in future PBL implementation. Similarly, Alyssa reflected on her experience working within an interdisciplinary team, acknowledging the shift in her perspective on content integration beyond college and career sessions by seeing how Amy applied her knowledge to the projects they were doing. "It helped me to realize how I can still incorporate these things" (post). Alyssa reflected on integrating career connections beyond her science focus, stating, "So they are [students] getting it from me, and they'll get it from her. So they'll be good to go…" (post). Alyssa further underscored the interdisciplinary nature of PBL and its capacity to integrate multiple STEM components, explaining that the students "had the science of the technology, and when I brought in the budget, that's where the math came in. And I guess you could say, engineer…" (post).

As a fifth-grade general education classroom, Kendra utilized her time in an interdisciplinary fashion. Using the novel Seedfolks as a shared reading experience, she aligned the PBL unit around gardening for the community. This unit also aligned with fifth-grade health standards by including the health benefits of the garden. They related the entire project to their ELA standards by writing an essay reflecting on the nutritional value of the recipes they could create from their garden. Kendra reflected on this process by saying, "Our school is one teacher per grade level, so participating in the AWAKE-STEM program forced us to like work in a team" (post). She explained that she usually did so when she made lesson plans by herself, but "AWAKE-STEM forced me to venture out and get the perspectives and assistance from the school counselor and the literacy coach."

STEM career exploration

Educator teams integrated STEM career exploration into the units by bringing in professionals from relevant fields. At HMS, the educators partnered with local farmers who provided seeds and vegetable plants and gardening and healthy eating advice for the students. The students also worked with their physical education teacher to learn about exercises and nutritious foods. A local chef allowed them to try recipes to understand healthy foods that could come from their garden. Finally, they worked with their cafeteria workers to understand the healthy foods served at their school and receive feedback on their recipes.

Before implementation, Viktor (HMS) highlighted the pivotal role of the school counselor in rural schools in facilitating students' access to career information related to STEM fields, such as computer technology, engineering, and mathematics. He emphasizes the school counselor's pivotal role: "Our school counselor plays a critical role in the AWAKE-STEM program by allowing kids to explore different fields." His statements underscored the essential role of the school counselor in rural schools to broaden students' awareness of career pathways, especially within STEM disciplines, through intentional exposure and guidance.

Similarly, after implementing their unit, Rita reflected on the value of PBL in bridging classroom activities with real-world career opportunities. Rita explains,

> There are so many more opportunities than just being limited to your basic police officer, firefighter, or teacher. Nothing wrong with those careers, but I feel like this was a good way for the students to get out and see that there are so many other careers that can come from STEM activities and PBL activities.

Rita's statement resonates with the idea that PBL facilitates skill-building and fosters career exploration. PBL encourages students to envision pathways to pursue STEM careers and allows them to

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connect the academic content they are learning to meaningful, real-world applications and futures. The HMS project integrated real-world applications of STEM education by engaging the students in designing and constructing a sustainable garden, fostering hands-on learning and problem-solving. While the HMS team could engage some community partners in their project, other industry partners could not meet their commitments—those who did honor their commitment provided valuable knowledge and resources, such as supplies and expertise. Due to these limitations, the HMS team felt that students' opportunities for direct industry exposure were limited and that this limited exposure hindered the project's full potential to create meaningful connections between students and STEM professionals.

EMS explored careers surrounding parks and recreation. While Wendy presented several career opportunities during her instruction (including architects, plumbers, and civil engineers), the Mayor gave them real-world feedback on their ideas. Emma stated, "The mayor was able to give students valuable feedback on their ideas and explain the process of real-world experiences such as taxes and raising funds for the recreation feature they may want to bring" (J2). Wendy stated that during her instruction "we talked about that person who would do that here [in our community] or like provided examples of [similar] companies or businesses that were in [masked county] that they could work at" (post). She also described how;

> the kids were able to find benefit in the PBLs, and they like doing the hands-on stuff, and they like learning about the careers…most of them actually gained a lot from it, and they learned 'oh well, I'm really good at this' or like 'I did not like that, you know, I'm interested in this' [instead].

In her interview, Wendy spoke about the intentional integration of career exploration within and outside the AWAKE-STEM program. Wendy discussed the value of expanding career discussions into the classroom, not solely within STEM lessons and ensuring that all students benefit from increased exposure to STEM career pathways. As noted, the EMS team planned a visit from the mayor, who provided the students with a firsthand look at government and urban planning careers and shared information regarding project planning, proposals, and budgeting, which Wendy noted as being tangible for their students.

Additionally, Wendy spoke about virtual job shadowing in their unit, allowing the students to explore engineering, plumbing, and architecture careers. While learning about these different career opportunities, students also gained valuable career knowledge such as different job responsibilities, required education, essential skills, salaries, and other career information. Wendy further noted in her journal that by using virtual job shadowing opportunities, her team could highlight the interconnectedness of different STEM careers and the value of working together to perform their roles.

TMS students took a field trip to local water treatment plants, learning about water-related careers and simulating real-world tasks like creating a budget for water conservation solutions. When discussing STEM career exploration in their classroom, Rachel noted, "It's so super important, and we [educators] cannot think where they are too young to understand or need to wait until high school to be exposed" (pre). She further emphasizes that when it comes to STEM career exploration, "the earlier, the better. Once the seed is planted, water it, nurture it, give it what it needs, and you never know because the future is limitless" (pre). Amy (TMS) and Wendy (EMS) spoke about setting up a career day that allowed for students to engage with different community partners as well as bringing in numerous other speakers during classroom guidance time, "lunch, and learns" (post), which incorporates the students learning about a field while eating lunch, all while building connections with local community STEM partners. Before engaging with the AWAKE-STEM program, Alyssa admitted, "Nothing is coming to me, as far as you know, like STEM connections" (pre). In contrast, Amy described how STEM career exploration was integrated into the classroom, explaining, "We integrated by bringing in community partners and business partners, but also using the [state] occupation information system website, where students are able to explore STEM careers" (post). Although students' final rain barrel products lacked authenticity through being designed but not created, Rachel emphasized that they "were exposed to procedures for testing, maintaining, and regulating procedures needed to monitor levels of water coming in and out of the plants, and connection to careers needed at all steps" (J1). She further highlighted the value of hands-on experiences, stating, "the tours of the facilities provided students training, true 'real-world' information shared from individuals working in that field, and 'on-the-job training' for future STEM workers" (J3). Students worked in rotating teams to enhance career exploration, each representing different roles relevant to the field. Rachel explained,

> I did not let them work just in one team, so at certain tasks through the PBL they were able to switch teams and work with different people, take on different roles. And we'll say they have grown from the first PBL to the second PBL—just the willingness to work with a different partner, take on different roles, and that I like" (post).

Amy reinforced the importance of exposing students to in-demand STEM careers, sharing, "I took the students there [wastewater plant] because it's a dying profession, and they need more wastewater treatment plant operators and lab technicians" (post). Additionally, Amy provided a specific example of STEM career exploration in action:

> We were able to discuss and identify problems and solutions that if water treatment plant operators do not do their jobs, then what could happen?...one student said if a plant operator does not test the water properly or daily, we could end up drinking or bathing in polluted water with bacteria (J1).

Through this process, students also applied soft skills to various plant positions, deepening their understanding of workplace roles. The teachers shared in their journals that students developed a stronger awareness of career opportunities, valuable workplace skills, and an appreciation for those working in STEM fields. Looking ahead, Alyssa expressed a desire "to truly be intentional about including my career spotlights in the lesson" (post), underscoring a continued commitment to integrating STEM career exploration into instruction.

Discussion

This case study illustrates how community- and career-focused PBL can be integrated into rural middle school STEM classrooms through educators' participation in a yearlong PD emphasizing teacher and school counselor collaborative PBL unit development. Rural STEM teachers often lack access to PD that links STEM education with career development, limiting their ability to prepare students for future careers (Dare et al., 2021). By exploring structured, collaborative PD, this study contributes to understanding how rural-focused approaches can bridge the gap between local needs and broader STEM education goals by integrating community assets and utilizing STEM career opportunities within content instruction. Our study also highlights the practical challenges of implementing PBE-focused project-based learning units as well as positive outcomes. This discussion will compare our research contributions with prior findings and identify potential areas for future exploration.

From the data, we observed varied degrees of integration of PBL design elements and integration of local community assets and STEM career opportunities across the different schools. Our findings suggest that our PD program provided teachers with tools to design and implement PBL units with community and career connections. Each team engaged their students with authentic adult community connections through field trips, engagement with community experts, or community improvement projects. Students engaged in applied learning opportunities to solve local problems and learn their content standards (academic rigor). For example, the community garden created by HMS was designed to become a central community hub that brought the classroom and the community together. This project succeeded both academically and socially, as it demonstrated the possibility of strengthening the bonds within the community through solving the community's need for locally accessible healthy foods. This idea aligns with Smith and Sobel (2010), who highlighted the benefits of leveraging local resources and expertise in education settings. However, unlike prior studies that emphasize benefits (Blumenfeld et al., 1994; Sobel, 2004; Thomas, 2000), our findings highlight the complexities and challenges of this integration. These findings included logistical issues and issues with the long term engagement of community experts, which could point to the need for more structured and reliable partnership models in rural schools. Gamse et al. (2017) support the need for additional studies in this area through their literature review of how STEM experts have contributed to students' increased STEM engagement in schools, citing a lack of consistent details on how STEM experts interact with students and a lack of methodological rigor in many studies. Understanding the nuances behind integrating community assets adds depth to the literature by showcasing the practical challenges educators face in rural environments, which can often be overlooked. The educator teams in our AWAKE-STEM program learned the value of reaching out and vetting many community partners to get commitments from a few, as well as the need to work with those experts throughout the PBL planning process to add more authenticity through local data sets, expert feedback on student product drafts, or to show students the relevance of content standards to local issues.

As found in previous studies of teachers' enactments of PBL units (Krall et al., 2023; Falik et al., 2008; Juuti et al., 2021), our teachers struggled with implementing some of the gold-standard design elements (Larmer et al., 2015). Our rural teams all scored at level 2 of Applied Learning for their second PBL unit implementations, often lacking the inclusion of opportunities for student-directed inquiry in which students use science and mathematics practices to solve local problems. These instructional modifications require changes to beliefs and practices (Lotter et al., 2007) and often take more than a year of PD and reflection, especially if teachers are moving to PBL from more traditional lecture-based instructional orientations (Mentzer et al., 2017). For example, Krall et al. (2023) engaged middle school teachers in developing watershed water quality PBL units after a week-long summer professional development and follow-up Saturday sessions during the academic year. Many teachers' units omitted key design elements, including student-driven inquiry investigations, authentic student-designed products, and community or expert interactions (Krall et al., 2023). Teachers often make small changes to their PBL instruction over time as they enact new strategies, reflect on what works, and adapt lessons further based on the needs of their students and their teaching context (Krajcik et al., 1994; Mentzer et al., 2017). In our educators' journals, which were written during their PBL unit implementations, teachers reflected on the need to include more student voice and choice, more student-directed inquiry, and the need to further adapt their units for their implementation in year 2 of the program. Our project staff has also reflected on needed changes to further support teams of educators in implementing PBL and have adjusted course curriculum and course timing to provide more support in the PBL design elements not assessed at the proficient level in year 1.

In addition to applied learning, two of the three school teams scored level 2 for Authenticity and Adult Connections due to a need to further plan authentic adult critique and revision opportunities, engage students in collecting and analyzing local data, and incorporate more authentic audiences for students' final product presentations or solution documents. Timing was a significant factor in year 1, with the team's second units ending near the time of state testing review, which at many of our small rural schools led to the end of regular instruction and school-wide testing review. In year 2 of the AWAKE-STEM PD, our teams are planning earlier enactments to avoid this conflict. Two teams also scored level 2 for Assessment Practices, utilizing primarily formative assessments, with limited focus on having students drive their learning and assess their progress toward project milestones. Although the educators all introduced their unit driving question through an engaging entry event, such as a field trip or community expert speaker, students did not often develop or revise their own need-to-know questions (student-led sustained inquiry) or revise products based on adult feedback using the final product rubrics. Rubrics were also teacher-created leading to limited student voice in how the final products were assessed.

The educator's PBL implementation strengths included creating PBL units strongly connected to their content standards with active engagement of collaborative teams of students in solving local community-based problems. In their journals and post-interviews, the educators described improved student engagement and interest during these units, fueling their continued participation and adaptation of their instructional practices.

All the teams' PBL units integrated common PBE elements with a focus on community improvement and natural resources, the inclusion of community-based experts, and an interdisciplinary content focus. PBE can allow teachers to "diminish the boundary between school and place, enlivening the curriculum and demonstrating to young people the immediate importance of what they are learning" (Smith and Sobel, 2010, p. 59). The school counselors on each team used their community connections and career expertise to contact many potential community partners related to the content being taught in each PBL unit. While the rural school team members encountered challenges with distance and schedules, all teams established initial community partnerships and reflected on how they might further engage community experts throughout their units in their second year implementations. School-community partnerships often take time to develop and cultivate (Rural School and Community Trust, 2003) and more support may be needed from our project to build a network of local rural community experts and STEM assets that can contribute to the PBL unit outcomes and student learning.

Integrating STEM career opportunities in our study also presented a unique comparison to the existing literature. While studies such as Dare et al. (2021) advocate for embedding career exploration in STEM education, our findings provided a more practical perspective on how this can be utilized in rural PBL settings. The integration of STEM careers was achieved through the collaboration of teachers and school counselors and the direct involvement of local professionals and real-world applications, which motivated students. We found that while there are significant benefits to implementing STEM career opportunities, such as increased relevance and student motivation, there are notable barriers in rural communities, such as limited industry presence. This contrast with the existing literature (Carr and Kefalas, 2009; Griffin and Galassi, 2010), which often presents a more idealized version of career integration, allows our study to contribute a realistic portrayal of what is feasible within the constraints of rural educational settings when teachers and school counselors work together to introduce middle school students to STEM careers within PBL units.

It is essential to highlight the practical challenges and potential educational outcomes of broadly applying PBL and PBE practices in rural settings. Our study sheds light on these challenges and outcomes, which are not often emphasized in the literature. The literature frequently focuses on PBL's potential to transform learning without fully addressing the infrastructural and professional development needs accompanying these transformations.

Implications

Teacher enactment of PBL

To value teacher and school counselor expertise and allow for stronger place-based connections within the educator created PBL unit plans, our PD program provided educator teams with professional learning through PBL coursework, a framework for gold-standard PBL, unit planning assistance, and follow-up coaching. Researcher-teacher collaboration is often a regular part of middle school PBL curriculum development, emphasizing collaborative planning, unit enactments, and reflective revision (Krajcik et al., 1994). As our teams implement their revised units for a second year and make further revisions, the units can be made available as models for other rural STEM teachers to adapt to their local contexts and community needs.

Small rural schools often engage educators in multiple roles beyond teaching students within their classrooms (Lotter et al., 2019). These additional duties and pressures to prepare students for high-stakes tests can interfere with teachers' enactments of new instructional practices. For example, Toolin (2004) described how school-based supports, such as the availability of collaborative planning time and resource allocations within middle schools, impacted teacher's PBL implementations in their PD program. Our PD program deliberately recruited teams of teachers and school counselors, engaging them in a collaborative planning model to spread the load and honor each educator's content expertise. We also provided support in the online courses through teams submitting segments of their units over time and receiving feedback from their peers, PBL instructors, and instructional coaches. Support continued during enactments, with coaches providing additional feedback via email check-ins, face-to-face or Zoom conferences, and feedback on video-recorded enactments. The courses also included weekly live meetings where teams could learn new strategies and collaborate across schools. Our research provides additional evidence that for teachers to transition to high-quality PBL instruction, they require sustained, supportive, and collaborative PD that takes their school contexts into account (Darling-Hammond et al., 2017).

School counselors' engagement in community and career integration

As school counselors continue to expand their roles in educational settings, integrating them more intentionally into PBL presents a valuable opportunity to enhance career readiness and student engagement. School counselors can enhance applied learning experiences through strategic collaboration by co-planning and co-teaching PBL units and working alongside educators to identify natural career connections within core content areas. Sustainable community partnerships support this effort by fostering ongoing relationships with industry experts, moving beyond one-time guest speaking events to more dynamic collaborations. Virtual tools and alumni networks can enhance accessibility and relatability in career exploration, serving as a starting point for industry connections and complementing community partnerships.

Broadening access to career exploration requires moving beyond traditional guidance models to offer immersive experiences. School counselors can be crucial in ensuring student engagement with community partners is structured around inquiry-based experiences rather than passive observation. They can collaborate with teachers to help students formulate career-relevant questions, facilitate problem-solving discussions, and connect students with industry professionals who can provide hands-on opportunities. Additionally, school counselors can actively strengthen feedback mechanisms between schools and industry partners by coordinating structured debrief sessions where students reflect on their experiences, identify skills gained, and receive constructive input from professionals. By facilitating these structured feedback loops, school counselors help ensure that career exploration remains an evolving, student-centered process. School counselors can also advocate for sustained industry involvement by organizing follow-up discussions or career mentoring sessions, reinforcing connections between academic content and real-world applications. Ensuring that all students, regardless of academic track, receive meaningful career exposure - particularly in high-demand fields like STEM - supports equity and fosters opportunities for long-term success (Irvin et al., 2019).

Rural community connections

Teachers and teacher educators must understand the importance and intricacies behind utilizing local resources, cultivating community partnerships, and interdisciplinary collaborative approaches (Smith and Sobel, 2010). This study has shown both the benefits and challenges of teacher created community and place-focused PBL units. To effectively implement PBL, teachers should be trained to identify and leverage local resources and partnerships within their school and the community, which are vital to providing real-world relevance to the PBL experiences and giving youth a sense of belonging and connection to their rural community (Gallay et al., 2016). Teacher educators should focus on developing these capabilities in pre-service and in-service training programs, ensuring teachers understand how to design and execute effective PBL strategies and collaborate with their school counselors to provide authentic STEM career connections to content standards.

Limitations and future research

The limitations section of our study acknowledges several key constraints that should be considered when interpreting the findings, particularly given that this research captures the first year of the program's implementation. This initial phase is critical as participants are typically still familiarizing themselves with the new intervention, adjusting to its demands, and refining their practice. Consequently, conclusions drawn from this first year should be approached with caution. Another limitation of this study is the potential research bias that arises due to the dual roles of the researchers. Three out of five researchers served as investigators in this study and as coaches to the participant teams, working closely with teams on refining their PBL units and supporting them in their implementation. One of the researchers acted as the instructor for two PBL courses, working closely with the participants to build and refine their plans. While researchers acted as participant observers (DeWalt and DeWalt, 2011), positionality was a key focus for researchers. The researchers used approaches to increase the trustworthiness of the data, such as member checks of the team rubrics and multiple raters for each analysis to limit the impact of researcher bias on the findings.

Additionally, the first year of implementation faced challenges with timing and initial setup that required rapid adjustments, impacting the effectiveness of the professional development program. These experiences have led to changes in the subsequent year, after the current unit of study. These adjustments include timing of the courses, the required implementation timing of the units, and clearer expectations regarding scheduling and check-ins. As part of a longitudinal study, the evaluation of the model's implementation and outcomes require iterative reflection and revision. This process of continuous improvement will continue throughout the implementation of the entire project.

The uniqueness of all rural communities and the small sample size provide another limitation of this study. Our study provides contextual insights into these particular settings by focusing on three distinctly different rural middle schools with dissimilar team make-ups. However, these cases may not reflect the broader circumstances in rural educational environments across different regions. As Squire et al. (2003) describe the unique local needs of each rural community, our findings offer valuable perspectives on the integration of PBL and PBE within these schools.

Future research can build on the findings from our current study to integrate community assets, PBE, and career development through PBL in rural settings. A critical area for further investigation is the collaboration between school counselors and teachers, a significant component of our model. Additional studies could analyze the dynamics of collaboration more deeply, as this was a limitation in the literature (Author et al., 2021a; Emihovich and Battaglia, 2000; Reiner et al., 2009). This research could examine how well teachers and school counselors understand their roles and how this awareness might impact the implementation of PBL and PBE. Additional future studies should assess the direct impact of community experts on student engagement and learning outcomes, exploring how their involvement could enrich students' educational experiences and increase their likelihood of pursuing STEM fields. Additionally, there is a need to measure the impact of these PBL units on student outcomes, specifically looking at student engagement, academic achievement, and subsequent interest in pursuing STEM careers.

Conclusion

The study's findings highlight the importance of leveraging community assets and career connections to enhance rural middle school STEM education. Our study and our PBL model provide valuable insights for researchers and practitioners who want to address educational inequities in underserved regions. Through community and career-focused STEM PBL units, rural educators have the potential to increase middle school students' interest in STEM content and future STEM careers while improving their rural communities through solving local community issues. Authentic community connections to STEM content and community experts bring value to rural places and showcase the cultural capital of community members, possibly leading to greater rural attachment and improved local STEM experiences (Gallay et al., 2016).

Data availability statement

The original contributions presented in the study are included in the article, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving humans were approved by University of South Carolina Ethics Review Board. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

DK: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. CL: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. LP: Conceptualization, Data curation, Formal analysis, Investigation, Writing – original draft. RG: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. DL: Conceptualization, Data curation, Funding acquisition, Project administration, Resources, Software, Supervision, Writing – original draft, Writing – review & editing.

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The authors declare that no Gen AI was used in the creation of this manuscript.

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