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Shaping change locally: a place-based STEM project's influence on rural elementary and middle grade students

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Introduction: Place-based education (PBE) seeks to integrate local environmental, cultural, and community contexts into learning. With instruction grounded in students' lived experience, this approach has the potential to enhance engagement and foster identity development, particularly in STEM disciplines. However, research on how PBE may influence STEM identity and agency development, especially in rural contexts, remains limited.

Methods: This study examines the effects of a place-based STEM project on fourth, fifth, and sixth-grade students in a rural school, focusing on identity affiliations, self-perception, and community engagement. Using a case study approach with elements of participatory action research, we analyzed pre- and post-project surveys, focus group interviews, and qualitative reflections.

Results: Findings indicate that students experienced significant shifts in their identity affiliations, particularly as advocates, problem-solvers, and community members. Students developed a stronger sense of environmental responsibility and STEM competence, engaging in authentic scientific inquiry and public advocacy. The project fostered interdisciplinary learning, real-world problem-solving, and strengthened students' sense of agency through their involvement in a local wildlife-vehicle collision mitigation effort.

Discussion: This study highlights the role of PBE in supporting STEM identity formation and civic engagement, demonstrating how locally relevant projects can empower students to see themselves as capable STEM learners and active community participants. The findings contribute to the growing body of research on place-based STEM education, emphasizing its potential for enhancing student engagement, agency, and identity development in rural contexts.

KEYWORDS
place-based, STEM, rural, elementary science, middle grades

Introduction

Place-based education (PBE) is a powerful approach to engage students in learning by connecting educational content to their local environment, culture, and community (Gruenewald, 2003; Gay, 2000; Smith, 2017). Rooted in the idea that learning should be relevant and grounded in students' lived experiences, PBE emphasizes the value of place in shaping students' understanding of academic subjects, especially in science, technology, engineering, and mathematics (STEM). This educational approach not only makes learning more engaging and meaningful for students but also fosters a sense of connection to their community, encouraging them to apply their knowledge to address local issues (Howard and Kern, 2019). These connections can significantly enhance students' engagement and motivation, particularly in rural settings, where access to quality STEM education and resources can be limited (Johnson et al., 2014).

STEM education in rural schools faces unique challenges that differ significantly from those in urban areas. Research has shown that rural schools often receive less funding, have limited access to high-quality STEM resources, and struggle to attract well-qualified teachers due to their remote locations (Miller and Votruba-Drzal, 2013; Provasnik, 2007). Despite these challenges, rural areas also present unique opportunities for STEM learning through place-based approaches that leverage local knowledge, community partnerships, and real-world problem-solving (Fraser et al., 2020). Engaging students in STEM through place-based projects can make these subjects feel more relevant and accessible, helping to demystify STEM fields and foster a sense of ownership over their learning process (Kennedy and Odell, 2014; Prendergast et al., 2014).

One of the most significant benefits of place-based STEM education is its potential to influence students' perceptions of self and how they see themselves, or their identity affiliations (Carlone and Johnson, 2007; Gee, 2000; Mercier and Carlone, 2021) in STEM. Students can often perceive STEM subjects as abstract and disconnected from their daily lives, which leads to disengagement and low participation rates (Britner and Pajares, 2006; Wang and Degol, 2013). However, when STEM learning is contextualized within students' own communities through place-based projects, it can positively influence their perception of these fields. Research indicates that when students engage with local environmental issues or community challenges, they develop a stronger sense of belonging and see themselves as capable contributors to their community's well-being (Gallay et al., 2020). This not only enhances their sense of competence and belongingness in STEM disciplines but also helps to build a more inclusive STEM identity, encouraging diverse student participation (Archer et al., 2013; Berger et al., 2020).

Despite the promising outcomes of rural PBE, STEM education remains underrepresented in the literature. Most research tends to focus either on STEM education or rural education as separate entities, leaving a gap in understanding how place-based approaches specifically benefit rural communities (Johnson et al., 2014). This oversight means that the unique educational needs and strengths of rural students are often overlooked in broader discussions of STEM pedagogy. Addressing this gap is crucial for developing more equitable and effective STEM learning experiences that empower rural students to see themselves as future STEM professionals and leaders in their communities (Gruenewald, 2003; Holmes et al., 2021; National Academies of Sciences, Engineering, and Medicine, 2024). We feel research into place-based, contextualized STEM education could provide valuable insights into how these approaches can be scaled and adapted to meet the diverse needs of rural learners.

Therefore, we explored the influence of a place-based, STEM experiences on the fourth, fifth, and sixth grade students who co-planned and participated in a locally contextualized place-based community impact project, or a student-centered project that addresses a real-world need, issue, or opportunity identified within the local community (Smith, 2002). The following research questions guided our exploration: *What is the impact of participating in a place-based STEM project on rural elementary and middle-grade students' self-perceptions? How does a rural, place-based STEM project shape elementary and middle-grade students' perceptions of self?* We explored these questions and the influence of place-based STEM experiences through the use of a pre-post, novel assessment tool and focus group interviews.

Literature review

PBE is a transformative pedagogical approach that emphasizes connecting learning experiences to the local environment and community, fostering deeper engagement and relevance for students. A place-based conceptual framework asserts that learning becomes more powerful when students can connect it to the world right outside their classroom doors (Getting Smart, 2017b; Sobel, 2004; Vander Ark et al., 2020). Rather than teaching subjects in isolation, this approach uses a student's surroundings as a living laboratory, allowing them to master academic content through hands-on experiences in their own community. Whether studying mathematics, literature, science, or history, students engage with the subject matter through meaningful connections to their local landscape and culture (Getting Smart, 2017b).

The influence of PBE extends beyond traditional academic outcomes, serving as a catalyst for both personal and civic development. Research shows that PBE supports students' development of environmental literacy and stewardship by grounding instruction in real-world contexts that reflect local ecological and cultural dynamics (Hamilton and Marckini-Polk, 2023; Vander Ark et al., 2020). This integration of classroom and community learning promotes students' emotional and social connections to their surroundings, cultivating a sense of belonging and agency (Vander Ark et al., 2020). As an immersive approach to learning, PBE enables students to develop practical problem-solving skills and social responsibility while cultivating a deeper sense of belonging and agency within their communities (Buxton, 2010). By integrating meaningful community engagement into the curriculum, PBE effectively prepares students for active participation in civic life while addressing real-world issues of local communities (Sturrock and Zandvliet, 2023).

Rural place-based education

Rural settings offer unique advantages for PBE by leveraging local contexts to engage students and develop community connections. When engaged in rural contexts, PBE encourages students to explore and reflect on their environment, leading to meaningful educational outcomes that align closely with the cultural and ecological realities of their communities (Corbett, 2020). This approach not only supports academic learning but also cultivates local pride, environmental stewardship, and leadership skills, fostering long-term community sustainability (Hamilton and Marckini-Polk, 2023; Sturrock and Zandvliet, 2023). In rural schools, PBE serves as a strategy for community survival, ensuring that both the school and the local way of life are sustained in the face of broader social and economic pressures (Howley et al., 2011a,b). The approach is particularly vital in rural contexts because it strengthens the bond between the school and its community while addressing contemporary challenges such as economic sustainability and environmental stewardship (Howley et al., 2011a,b).

The application of PBE in rural education involves deep collaboration between schools, local experts, and community organizations, making the learning process more dynamic and interdisciplinary (Langran and DeWitt, 2020). For example, rural schools implement PBE through annual traditions such as fall expeditions with hands-on outdoor activities, knowledge fairs where students present to the community, and long-term projects like boat-building, electric vehicle projects, and local journalism units that integrate local history and environmental stewardship directly into the curriculum (Howley et al., 2011a,b). These practices transform the classroom into a dynamic space where students learn by interacting with their environment and drawing on the community's unique funds of knowledge (Cruz et al., 2018). In rural schools, PBE manifests through projects like learning traditional Indigenous practices, participating in aquaculture projects, and working on initiatives that connect students with local industries and cultural heritage (Bartholomaeus, 2006).

PBE allows students to connect academic content with their lived experiences, promoting both personal growth and community well-being. This alignment between education and local culture is particularly critical in rural settings, where students develop stronger critical thinking skills, environmental awareness, and civic responsibility (Howley et al., 2011a,b). The benefits on students is multifaceted – they gain practical skills and a deep understanding of local issues while developing greater agency and responsibility that benefits both their personal development and their communities' socio-economic and environmental well-being (Cruz et al., 2018). Furthermore, PBE helps combat student disengagement by fostering a deeper connection to place and encouraging them to contribute positively to their communities rather than seeking opportunities elsewhere (Bartholomaeus, 2006). When education is deeply connected to place, students gain a stronger sense of identity and belonging, increased engagement, and enhanced academic achievement, while developing practical skills and critical awareness that empowers them to participate actively in their communities' future (Corbett, 2020).

Influences of place-based education

The benefits of PBE extend beyond academic achievement to deeply contribute to students' sense of identity, belonging, agency, and motivation (Sobel, 2004; Vander Ark et al., 2020). By embedding learning within local environments and real-world contexts, PBE fosters a strong sense of place and community, allowing students to develop meaningful connections to their surroundings. Learning experiences grounded in place shape students' identities and perceptions of self, as they come to see themselves as active participants in their communities rather than passive learners in a classroom (Fisher, 2018). These perceptions of self, also known as self-concepts, reflect the ways individuals see, understand, and evaluate themselves based on their experiences, abilities, and social comparisons within different environments (Pajares and Schunk, 2002; Schunk, 2020).

PBE plays a crucial role in shaping students' self-perceptions by embedding learning within local environments and real-world contexts. Fostering a strong sense of place and community also helps students see themselves as active participants rather than passive learners, strengthening their sense of identity (Sobel, 2004; Vander Ark et al., 2020). Gee (2000) argues that identity is shaped through participation in meaningful social practices, and PBE provides students with authentic experiences that allow them to enact and develop new identities—whether as environmental stewards, civic leaders, or scientific investigators (Mercier and Carlone, 2022).

Science identity, a specific dimension of identity and self-perception, is shaped by students' experiences and interactions within science learning environments (Stroupe and Carlone, 2022; Carlone and Johnson, 2007). It consists of three interrelated components that influence whether students see themselves as "science people": (a) competence (e.g., having knowledge and understanding of science content and practices), (b) performance (e.g., demonstrating scientific knowledge through discourse, sensemaking, or problem-solving), and (c) recognition (e.g., being acknowledged by oneself and others as a certain kind of person; Carlone and Johnson, 2007). The integration of PBE with STEM education can enhance all three components of science identity, as students engage in authentic, place-based scientific inquiry that reinforces their competence, provides opportunities for meaningful performance, and fosters recognition within their communities. By connecting learning to students' lived experiences and encouraging active participation, both PBE and self-perception and science identity frameworks emphasize the role of social context in shaping how students come to see themselves as capable and engaged learners.

In STEM, PBE connects students' learning experiences to their local environments and communities, shaping how they view themselves, especially as learners and doers of science or STEM (Smith, 2002; Zimmerman and Weible, 2017). Research by Semken and Freeman (2008) demonstrated that when students engaged with scientific concepts through the lens of their local surroundings, they developed stronger connections between affiliations with personal identities and scientific practices. Studies have also shown that place-based approaches benefit students who may feel disconnected from traditional science education. For instance, Barton and Tan (2010) found that urban middle school students developed stronger science identities when they investigated environmental issues in their neighborhoods. When engaged in this kind of learning, students saw themselves as legitimate producers of scientific knowledge rather than passive recipients. This approach validated students' lived experiences and cultural knowledge, transforming their relationship with science from one of potential alienation to one of meaningful engagement and personal relevance. By grounding STEM inquiry in familiar contexts, PBE helped students recognize that science is not just something that happens in disconnected contexts but is deeply connected to their daily lives and communities.

Engaging with place enables students to take ownership of their learning, thereby enhancing their sense of agency (Vander Ark et al., 2020). By working on community-based projects, students learn that their contributions matter, leading to increased motivation and a deeper investment in their education. When students engage with local issues and community partners, they begin to see themselves not just as students, but as valuable contributors to their communities' wellbeing and development (Sobel, 2004; Vander Ark et al., 2020). Chawla and Derr (2012) found that youth who participated in community-based environmental projects developed increased self-efficacy and agency, beginning to view themselves as capable change agents within their communities. This shift in self-perception can extend beyond environmental science contexts—students who engage in PBE develop stronger civic identities and see themselves as

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individuals who can make meaningful contributions to society (Anderson, 2017; Sobel, 2004). Studies have shown that when students work alongside community members and local experts in authentic problem-solving situations, they develop more sophisticated understandings of their own capabilities (Birmingham and Calabrese Barton, 2014). The collaborative nature of PBE, where students work with community members to address real local challenges, helps students see themselves as both knowledge builders, community leaders, and capable change agents.

Place-based STEM education

Place-based STEM education integrates science, technology, engineering, and mathematics with local environmental and cultural contexts, enhancing both academic and practical learning outcomes for students. By situating STEM learning in real-world local problems, students develop a deeper understanding of scientific concepts while engaging in meaningful community-based projects. Research demonstrates that this approach not only improves student engagement in STEM fields but also fosters a sense of agency, environmental stewardship, and willingness to participate in community improvement projects (Hamilton and Marckini-Polk, 2023; Semken and Freeman, 2008; Zimmerman and Weible, 2017). For example, place-based STEM initiatives in rural and urban schools have led to increased interest in ecological sustainability, as students apply their scientific knowledge to address pressing local issues like water quality or renewable energy solutions.

Aligning closely with the three-dimensional teaching and learning framework of the Next Generation Science Standards (NGSS) (NGSS Lead States, 2013), placed-based STEM education emphasizes disciplinary core ideas, crosscutting concepts, and science and engineering practices. By anchoring STEM instruction in local contexts, PBE provides students with opportunities to engage in authentic scientific inquiry and problem-solving within their own communities. As Anderson (2017) states, "Place-based education extends learning into both nature and the human-made aspect of a community. Learning revolves around environment, culture, economics, and governance" (p. 1). This broad contextualization supports students in developing deeper conceptual understandings (disciplinary core ideas), recognizing patterns and connections across disciplines (crosscutting concepts), and engaging in scientific practices such as modeling, argumentation, and investigation. Furthermore, place-based STEM education naturally integrates engineering design, as students work to address local challenges, reinforcing the NGSS vision of science as an iterative and applied process (Cody and Biggers, 2019).

Some studies have highlighted the effectiveness of place-based STEM education. A study by Ballard et al. (2023) showed that students participating in community-driven STEM projects developed critical problem-solving skills while addressing local environmental concerns. Additionally, Zandvliet and Brown (2006) explored how integrating place-based STEM into the curriculum encouraged students to think critically about sustainability and resource management. These projects allowed students to move beyond theoretical learning by engaging in data collection and analysis directly related to their local environments. Place-based STEM education has been shown to bridge the gap between classroom learning and real-world applications, fostering long-term interest in the STEM field, particularly among underserved populations (Gallay et al., 2020; Vander Ark et al., 2020), suggesting that connecting STEM learning to students' lived experiences significantly enhances their perceptions of belonging, motivation, and agency.

Lee (2020) argued that learning experience utilizing phenomena relevant to students' lives, promoted equity and engagement in NGSS-aligned STEM instruction. The study, a fifth-grade unit on garbage and landfills, demonstrated how a focus on local phenomena led to the successful integration of place-based learning. This, in turn, promoted equity, engagement, and rigorous STEM learning by connecting to students' lived experiences with project-based learning, which promote three-dimensional STEM learning through sustained investigation, incorporating multiple performance expectations over time (Lee, 2020). When students engaged with local phenomena and community-based problems, they simultaneously developed scientific practices while recognizing crosscutting patterns that connected their immediate environment to broader scientific principles (German et al., 2023). In this way, integration of PBE with three-dimensional STEM instruction created meaningful connections between abstract scientific concepts and students' lived experiences, leading to deeper understanding and increased engagement (Rongstad Strong et al., 2023). By situating learning within meaningful local contexts, place-based approaches cultivate student agency, connect science to lived experiences, and make STEM learning more relevant, rigorous, and equitable (Lee, 2020).

Framework

In this study we use PBE as both an instruction approach and conceptual framework for STEM teaching and learning. As both an approach and a framework, it connects student learning to local communities, leveraging geographic, cultural, and environmental contexts that deepens student engagement and academic outcomes (Getting Smart, 2017a, 2017b). In this study, we adapted a framework for PBE to be STEM specific (see Figure 1; Teton Science Schools,

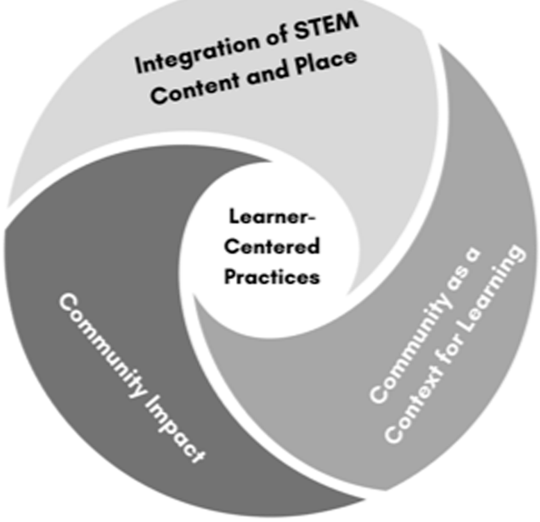

FIGURE 1
Place-based education framework, specific to STEM (adapted from Teton Science Schools, n.d.).

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n.d.). The provided framework highlights four key elements of PBE—integration of STEM content with place, community leveraged as a context for learning, and a focus on community impact, all anchored in and centered on learner-centered instruction practices (Teton Science Schools, n.d.; Vander Ark et al., 2020). This framework aligns with the broader goals of PBE, which emphasize interdisciplinary, inquiry-based, and experiential learning, fostering student agency and deeper connections to real-world issues (Anderson, 2017; Vander Ark et al., 2020). By embedding STEM concepts in local settings, educators can create opportunities for students to explore authentic problems, develop a sense of responsibility for their communities, and build skills in problem-solving and critical thinking. Additionally, using the community as a learning environment ensures that education is relevant and meaningful, encouraging students to see themselves as active contributors to their local and global ecosystems (Anderson, 2017; Getting Smart, 2017b; Vander Ark et al., 2020).

Methods

In our exploration of a place-based, STEM project and its impacts on students' self-perceptions and ways in which they saw themselves, we utilized a case study approach. This approach, as outlined by Merriam (1998), was appropriate because it allowed for an in-depth exploration of the complexities and nuances of a place-based, STEM project in a rural school. Case study methodology is particularly well-suited to capturing the rich, contextual details of how the pedagogical affordances of PBE influenced teaching practices and how students' identities and self-perceptions were shaped and influenced throughout the project (Merriam, 1998; Stake, 1995). This approach facilitated a comprehensive understanding of the interactions between students, teachers, and the community within their authentic environment. It also provided the flexibility to examine multiple facets of the experience, making it possible to uncover the unique affordances and challenges inherent in this educational setting.

Furthermore, our case study approach was informed by and adapted elements of a participatory action research (PAR) design. According to Chevalier and Buckles (2013), PAR addresses "the idea that research must be done 'with' people and not 'on' or 'for' people" (p. i). As the practices of place-based education often result in complex outcomes for students, teachers, and communities, a participatory approach to defining the resulting outcomes of PBE implementation can lead to more dynamic and nuanced understandings. Grounding understanding of these outcomes in a co-produced and participatory approach can help to ensure that documented outcomes are more relevant and valued by the populations engaging in the research (Pain et al., 2015). Therefore, the planning and design of this study were carried out in a collaborative and iterative fashion with the teachers and, through their involvement and consultation, the class students directly involved in the study.

Research context

The school and students

For some, the word *rural* conjures mental images of a small, wooden, one-room schoolhouse distanced from the nearest town or urban center (Greenough and Nelson, 2015). Willow Fork School (a pseudonym, blinded for review) is a *rural remote* school, meaning that the town of Willow Fork is classified as rural by the latest United States Census Report (National Center for Education Statistics, 2021) and that both the school and the community are more than 10 miles away from the nearest urban cluster or populated area of between 2,500 and 49,999 people. However, the rural remote school of Willow Fork is nowhere close to a small, one-room schoolhouse. Willow Fork School is a rural school in the southeast corner of a Mountain West state. The school serves approximately 90 students in grades Kindergarten through 12 in a multi-story, sprawling school campus in the heart of the town of Willow Fork, which has a population of approximately 220 (U.S. Census Bureau, 2021).

Due to its small population and rural context, Willow Fork School is multi-generational. Most families have seen two or three generations move through the school. Approximately half of the teachers have taught at Willow Fork for over 15 years, teaching multiple sets of siblings, generations of families, and even their own children and, in some cases, grandchildren. We worked with two classes of students for this study. We chose these two classes due to their involvement in the Highway 13 project. The two classes involved in this study were the fourth-fifth grade classroom and the sixth-grade classroom. Together, the two, multi-age classrooms contained 16 students (six fourth graders, five fifth graders, and five sixth graders), ages nine to 12 years old. Of those 16 students, nine identified as female and seven as male, and all students identified as white.

The highway 13 project

During the 2023–2024 academic year, Willow Fork elementary students and teachers initiated a place-based, STEM project focused on addressing a local community issue – frequent wildlife-vehicle collisions along Highway 13 (see Figure 2a). At the start of the year, Willow Fork elementary students began to observe an alarming number of collision incidents along this local highway near the school. Accordingly, elementary teachers began to scaffold a series of place-based investigations to build student understanding of this issue's scope. These activities included a bus trip along the highway to observe collision incidents and wildlife habitat, and an analysis of data available through the State Department of Transportation (SDOT; blinded for review). Following the site visit, students studied the various habitats along the highway and began to uncover why such a wide variety of wildlife lives and migrates along the highway area. To further explore this local wildlife diversity, each student chose an animal and crafted a detailed report on the animal.

Using these insights, the students created a detailed map highlighting high-incident areas and investigated possible causes (see Figure 2b). After plotting of the animal carcasses, students were able to identify definite areas of collision incidents along the highway. As the current highway speed limit is consistent across the full length of Highway 13, students wanted to investigate the effects of different speeds on stopping distance potential. Teachers and students created a simulation where they used bicycles to replicate this phenomenon (see Figure 2c). Each student rode at a slow pace and measured stopping distance and then again at a higher rate of speed. They looked at the data collected and concluded that stopping distance greatly increased with an increase of speed.

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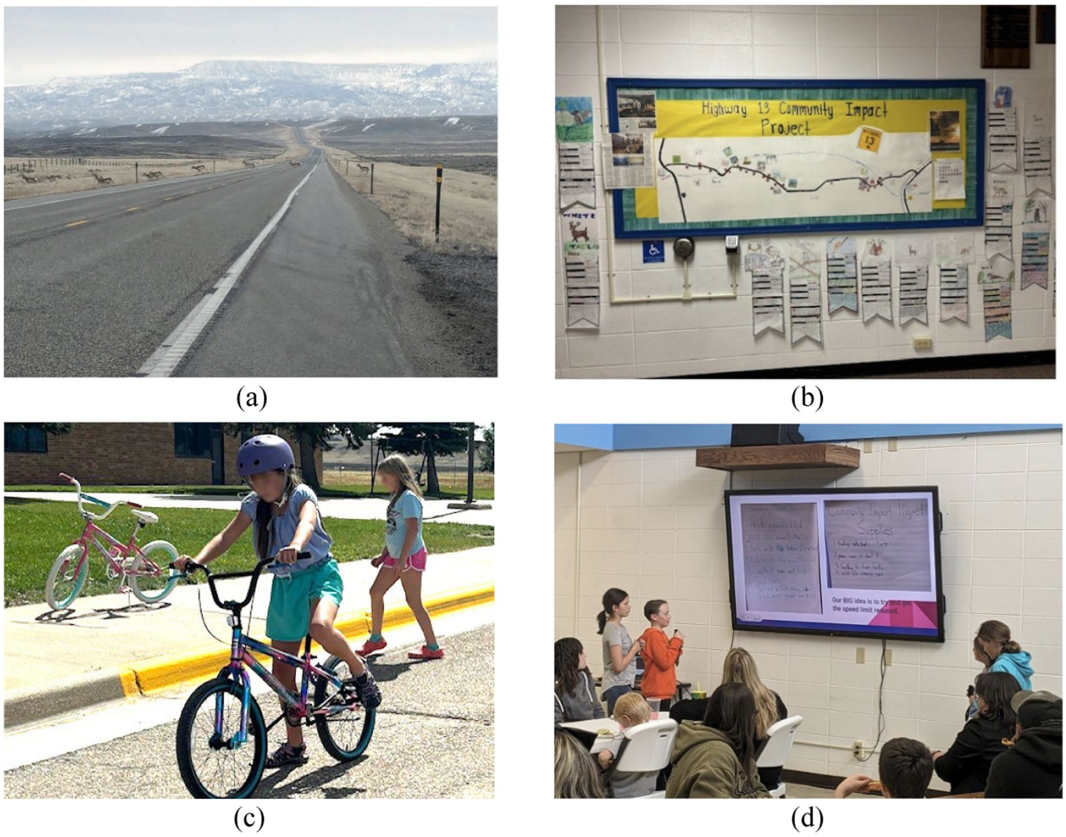

FIGURE 2
Progression of the Highway 13 project. **(a)** students identified wildlife crossing roadways as a common and problematic occurrence in their area; **(b)** students' map of local wildlife-vehicle collisions and animal reports; **(c)** students using bicycles to simulate the effects of stopping distance; **(d)** presenting findings and offering discussions about potential solutions.

Students then collaborated with local residents, ranchers, SDOT, State Game and Fish (blinded for review), and even the Governor's office, to explore the realities of public advocacy and potential solutions. The project is actively culminating with students presenting findings to their local community, local school board, and to the State Engineer's office (see Figure 2d). A primary point within these student presentations includes recommendations for mitigating future collisions. Their next major contact will be to try and work with the Game and Fish department and brainstorm the possibilities of additional signs of different types to be placed along the highway. This place-based project not only engaged students to investigate real-world challenges but also highlighted their role in shaping meaningful, community-driven solutions.

Data collection and analysis

The data collected for this case study provided multiple perspectives and rich context for understanding the impact of the place-based STEM project. To measure students' self-perceptions during the place-based STEM project, we administered a survey at two key points: once at the beginning of the school year, before the project began, and again at the end of the school year, close to the project's completion. The second survey administration was followed by a focus group interview with participating students ($n = 13$; only 13 students were present that day) to ascertain their insights into the data.

Data collection

The survey we created was a pre- and post-project design to measure the anticipated outcomes of student involvement in the place-based community impact project (Smith, 2002). In this study, the research team made a commitment to collaboration and iteration in data collection by proposing, workshopping, and applying feedback from the teachers and students to survey questions (Kemmis et al., 2014). There were two main parts to the survey – identity affiliation and student impact (Kuh, 2008). The identity affiliation section asked students to highlight words or phrases in one of three colors to indicate how much they felt like this word or phrase represented them in general and while engaged in the Highway 13 project. The words and phrases in this section of the survey included *Scientist, Artist, Advocate, Inventor, Good Community Member, Leader, Problem Solver, Investigator,* and *Communicator*. We arrived at these words and phrases through a collaborative process with the project teachers where the teachers described desired student outcomes, the research team synthesized the outcomes into a list of words and phrases, and teachers chose the words and phrases they felt were most appropriate.

The second part of the survey, focusing on student impact, consisted of a set of items that asked students for their perceptions of certain constructs. These constructs (i.e., environmental responsibility, character development and leadership, self-esteem, sense of classroom community, cooperative teamwork, environmental interest and concern, sense of environmental stewardship, project engagement, self-efficacy, community leadership, community impact, personal growth, deepening of relationships, and academic growth) align with what Kuh (2008) calls high-impact practices, which produce outcomes assessed under the umbrella of student impact.

All questions were asked using a 5-point Likert agreement scale (Joshi et al., 2015). Through prior project work, the research team developed a list of survey constructs and questions that addressed a range of outcome constructs theorized to emerge from participation in community impact projects. Table 1 details the survey constructs, their foundational literature, and gives examples of items for each construct. We shared a large bank of survey items with the involved teachers who then reviewed the items and offered suggestions to the research team about which items should be utilized. Once the survey recommendations were shared back to the research team, we used the feedback to craft the final survey. As this study has element inspired by PAR (Chevalier and Buckles, 2013), the selection of survey items was co-constructed with educators and students, resulting in variable item counts across constructs. Our collaborative approach to the survey development prioritized local relevance and participant voice over uniform scale length, and while some constructs were represented by only one or two items, the survey reflects the community-driven nature of the both the Highway 13 Project and its assessment.

The second phase of data collection employed a focus group methodology to gather interpretive insights from the participating students. Drawing on focus group recommendations Gibson (2012) and Hennessy and Heary (2005), we conducted a structured discussion that served two main purposes – attaining students' perspectives of the survey data and understanding what experiences they felt contributed to the survey data. We designed a focus group protocol that began with asking participants (i.e., 13 fourth, fifth, and sixth grade students) to talk about their favorite parts of the Highway 13 project. This stimulated students' memories and recollections of the project, and established the light, conversational tone of the focus group.

Next, in the main part of the protocol, we presented participants with the survey results and invited them to evaluate and critique the findings, addressing questions of validity and offering alternative interpretations where appropriate. The next phase of the focus group protocol focused on the most relevant and statistically significant survey results. For each survey category of focus, we asked two questions. First, we presented students with the survey results for a specific category and invited them to evaluate and critique the findings, addressing questions of validity and offering alternative interpretations where appropriate. An example of this was, *The survey showed that during the Highway 13 project many students' sense of environmental responsibility increased. Does this make sense to you? Why is that?* Then, students were specifically prompted to reflect on the statistically significant survey results in relation to the Highway 13 project. We asked students to explore potential causal mechanisms and contextual factors that might explain these outcomes. For example, we asked *What was it about the Highway 13 project that might have led you or your classmates to feel more responsible for the environment*? We repeated this question set until we had addressed all data points presenting notable and statistically significant changes.

TABLE 1 Survey constructs, example items, and citations.

Survey construct	Example item	Citation	Number of items in the final survey
Environmental responsibility	My actions impact the health of the environment.	Stern et al. (2010)	$n = 4$
Character development and leadership	I talk to my family or friends outside of school about what I've learned.	Stern et al. (2010)	$n = 4$
Self esteem	When I try something, I am confident I will succeed.	Kearney (2009)	$n = 2$
Sense of classroom community	Students in my class care about each other.	Kearney (2009)	$n = 2$
Cooperative teamwork	I like cooperating in a team with other kids in my class.	Kearney (2009)	$n = 1$
Environmental interest and concern	I think that protecting and saving natural resources (like plants, animals, water, and air) is important.	Kearney (2009)	$n = 3$
Sense of environmental stewardship	I believe that I have a personal responsibility to help the environment.	Kearney (2009)	$n = 2$
Project engagement	I often get so focused on a project that I lose track of time.	Fredricks et al. (2004); Panorama Education (2020)	$n = 2$
Self-efficacy	When complicated ideas come up in projects, I am confident that I can understand them.	Panorama Education (2020), Usher and Pajares (2008)	$n = 1$
Community leadership	This project helps me understand my community better.	Welsh et al. (2022)	$n = 2$
Community impact	I have the knowledge and skills to positively impact my community.	Welsh et al. (2022)	$n = 2$
Personal growth	School projects improve my leadership skills.	Welsh et al. (2022)	$n = 1$
Deepening of relationships	If I need support, I can turn to my peers.	Welsh et al. (2022)	$n = 4$
Academic growth	This project supported my academic growth (growth as a student).	Welsh et al. (2022)	$n = 1$

This approach allowed us to use the qualitative insights to inform our quantitative findings while engaging participants as active interpreters of the research results.

We concluded the focus group interview by asking participants about what they learned while participating in the Highway 13 project and for any last thoughts or ideas that they wanted to add to the discussion. The focus group interview was audio recorded, and following we transcribed the recording verbatim in preparation for data analysis.

Data analysis

Survey data

We first analyzed the student survey data. This step in the data analysis process was followed by analysis of the focus group interview data which helped to provide a more nuanced explanation of the student survey results. Twelve of the total 16 participating students completed both the pre- and post-identity affiliation survey, and therefore only this paired data was analyzed for this survey portion. In order to analyze the identity affiliation data in the first part of the student survey, we first tallied students' responses in each affiliation category ("Like Me," "Sort of Like Me," and "Not Like Me") from both the pre- and post-project surveys. This allowed us to see the initial and final distributions of how students identified with each role before starting and while engaged in the Highway 13 Project. We then examined growth within each category by tracking individual changes. For instance, if a student shifted from "Not Like Me" in the pre-project survey to "Sort of Like Me" in the post-project survey, this was considered a positive change (+1) because they moved up to the next category. Similarly, if a student moved from "Not Like Me" to "Like Me," it counted as a + 2, reflecting a greater shift in affiliation. Conversely, declines were marked as negative changes; for example, a shift from "Like Me" to "Sort of Like Me" was recorded as −1, signifying a reduction in that identity affiliation. This process is illustrated in Figure 3.

After calculating these individual shifts, we summed the total positive and negative changes across the class (see Figure 3) to determine the overall growth in each identity affiliation category. This final tally helped us capture the extent of identity affiliation shifts for the entire group, allowing us to identify which affiliations saw the most substantial increases, declines, or remained relatively stable. By examining these aggregate changes, we gained insights into how students' self-perceptions as scientists, advocates, community members, and other roles evolved throughout the course of the project.

To analyze the Likert scale data in the second part of the student survey, we compared students' pre- and post-project scores ($n = 12$) across the constructs to assess the student impacts of the Highway 13 Project. Each student completed surveys at two points—before and after the project—allowing us to measure changes in various areas of self-perception such as community leadership, environmental responsibility, and self-efficacy. To determine the appropriate statistical approach for analyzing changes in students' scores from pre- to post-survey, we first assessed the normality of the data using the Shapiro–Wilk test. This test was chosen due to its sensitivity to departures from normality, particularly with small sample sizes (Razali and Wah, 2011; Shapiro and Wilk, 1965). The results revealed that several constructs were approximately normally distributed ($p > 0.05$), while others significantly deviated from normality ($p \leq 0.05$; see Table 2). Given these mixed results, we proceeded with a conservative analytical approach and conducted Wilcoxon signed-rank tests—a non-parametric alternative to the paired t-test that does not assume a normal distribution (Meek et al., 2007; Wilcoxon, 1950). In this way we compared students' pre- and post-project scores (n = 12) across the constructs to assess the student impacts of the Highway 13 Project. This allowed for a robust examination of within-subject changes across all constructs.

Focus group data

In our qualitative data analysis of focus group interview data, we adopted a multi-pass coding process to explore the nuances found in the data. Our initial coding focused on identifying mentions of key program elements, how students perceived themselves, notable outcomes, and overall student influence (Saldaña, 2021). This first pass provided a kind of organizational framework, which allowed us to catalog recurring themes and specific references that aligned with the affiliation categories, constructs, and our research focus. By highlighting these areas, we established a foundation for more detailed analysis, helping us distinguish prominent aspects of the program and initial patterns in student and teacher perspectives.

Following the first coding pass, we conducted a second, more interpretive read-through, concentrating on the segments previously marked. This phase aimed to understand the reasons behind observed shifts in the data—why teachers and students felt certain outcomes or changes occurred (Saldaña, 2021). By examining the language used to describe experiences, we uncovered insights into participants' perspectives on the underlying causes of changes in self-perception and program engagement. This iterative coding process enabled us to move beyond surface-level patterns, leading to a richer understanding of the program's influence on student identity affiliations, self-perceptions, and outcomes.

Findings

The Highway 13 Project was not only a fixture of the fourth, fifth, and sixth graders' classroom and STEM experiences for most of the school year, it was a topic of conversation throughout the school and the community of Willow Fork. Needless to say, the effect of the Highway 13 Project extended well beyond the fourth, fifth, and sixth graders, though it had a profound effect on these students. We surveyed the students at the beginning of the Highway 13 Project and at the end of the school year. We explicitly say "at the end of the school year" and not "at the end of the Highway 13 Project" because by the end of the academic year, the teachers and students had brought the Highway 13 Project to a pause, but planned to continue its work into the next school year. The survey focused on modes of engagement or identity affiliations (Mercier and Carlone, 2021) and how students might see themselves or affiliate both before and during their participation in the Highway 13 Project. The next sections first describe the survey data and changes that students did (or did not) perceive while participating in the Highway 13 Project. Those findings are followed by sections that highlight thematic interpretations of shifts in identity and self-perceptions. Importantly, we describe how engagement in the Highway 13 Project, as supported by focus group interview data, shaped student identity affiliations and self-perceptions.

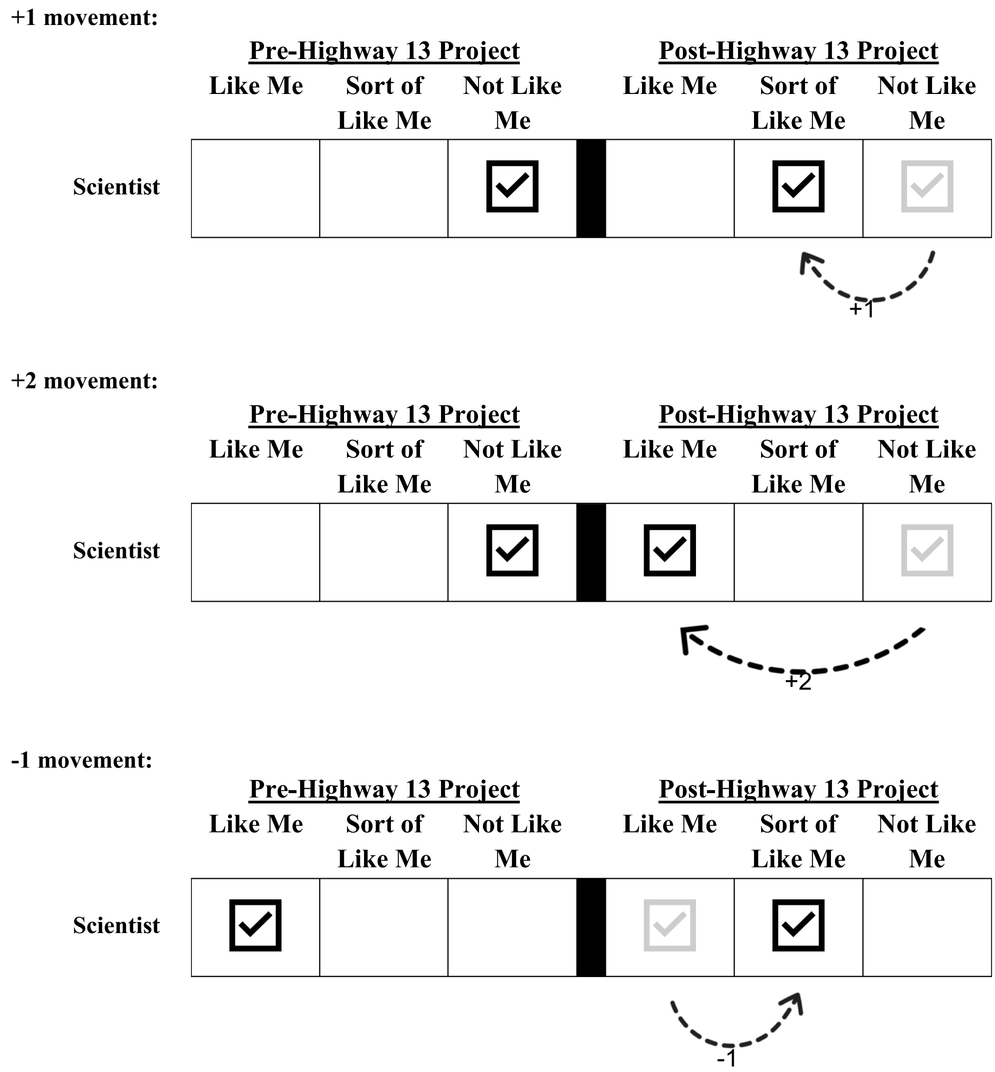

FIGURE 3
Examples of affiliation movement and scoring in the data analysis process.

Identity affiliations and self-perceptions

To explore how the Highway 13 Project influenced students' self-perceptions, we examined how they identified with affiliations over time. Identity affiliations refer to how students saw themselves in various roles, such as scientists, problem solvers, and community members, both before and during their participation in the project. Students reported the extent to which they identified with each role using three categories: "Like Me," "Sort of Like Me," and "Not Like Me." The results, shown in Figure 3, capture shifts in these affiliations over the course of the project, highlighting areas of growth or decline in how students related to different identities.

The results in Figure 4 highlight how students' identity affiliations shifted while working on the Highway 13 Project. Several affiliation categories, such as Advocate and Problem Solver, saw notable increases. For example, the number of students affiliating as an advocate increased from one to five in the "Like Me" category, reflecting a net positive change of +7. Similarly, the Problem Solver affiliation saw substantial shifts, with four students strongly affiliating with this role while engaged with the Highway 13 Project compared to only one before. This also resulted in a + 7 net change. These results suggest that the project may have fostered students' sense of themselves as advocates and problem solvers, likely due to the project's focus on community engagement, real-world environmental challenges, and community impact.

Other identity affiliations showed more subtle shifts. For instance, the Scientist category increased moderately, with six students identifying that a scientist was "Like Me" while working on the project, compared to three initially, resulting in a net change of +4. Similarly, the Inventor and Good Community Member categories both increased by +5, indicating that students developed greater affiliation with these roles while engaged with the project. Overall, these shifts in identity affiliations reflect the project's influence on students' self-concept, especially in roles that align with problem-solving, advocacy, and community involvement.

To assess the impact of the Highway 13 Project on students' development across multiple constructs, we conducted Wilcoxon signed-rank tests comparing pre- and post-Highway 13 Project scores

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TABLE 2 Shapiro-Wilx test results.

Category	Survey time	W statistic	*p*-value
Community leadership	Pre	0.840	0.033
Community leadership	Post	0.870	0.066
Environmental responsibility	Pre	0.894	0.133
Environmental responsibility	Post	0.924	0.325
Character development	Pre	0.877	0.079
Character development	Post	0.877	0.080
Self esteem	Pre	0.927	0.353
Self esteem	Post	0.823	0.017
Sense of classroom community	Pre	0.919	0.276
Sense of classroom community	Post	0.881	0.089
Cooperative teamwork	Pre	0.851	0.038
Cooperative teamwork	Post	0.754	0.003
Project engagement	Pre	0.815	0.013
Project engagement	Post	0.785	0.006
Environmental interest and concern	Pre	0.835	0.024
Environmental interest and concern	Post	0.919	0.284
Community impact	Pre	0.745	0.002
Community impact	Post	0.852	0.039
Project growth	Pre	0.813	0.013
Project growth	Post	0.798	0.009
Deepening relationships	Pre	0.764	0.003
Deepening relationships	Post	0.919	0.277
Academic growth	Pre	0.773	0.005
Academic growth	Post	0.787	0.007

($n = 12$). These tests aimed to identify any significant changes in areas (i.e., Community Leadership, Environmental Responsibility, Character Development, Self-Efficacy, Sense of Classroom Community, Cooperative Teamwork, Project Engagement, Environmental Interest and Concern, Community Impact, Project Growth, and Deepening of Relationships). Table 3 presents the results of these analyses, detailing the W statistics and *p*-values. The following paragraphs summarize the key findings, highlighting which constructs exhibited significant change and which remained stable over the course of the project.

Upon initial examination, many of the constructs appeared to have changed from the before students began the Highway 13 Project to when they completed the survey at the end of the school year, while they working to complete the project. Results from the Wilcoxon signed-rank tests (see Table 2) revealed a statistically significant increase in scores for only Environmental Responsibility ($W = 1.5$, $p = 0.019$), suggesting that the students felt more responsible for environmental issues as they worked on and after the project and that their sense of environmental responsibility improved meaningfully as they engaged in the Highway 13 Project.

No statistically significant differences were observed in the other categories, such as Community Leadership ($W = 9.0$, $p = 0.380$), Character Development ($W = 24.5$, $p = 0.447$), Self-Esteem ($W = 17.0$, $p = 0.154$), and Classroom Community ($W = 17.0$, $p = 0.887$), indicating minimal or no measurable impact in those areas through participation in the Highway 13 Project. These results indicate that while the Highway 13 Project may have had broad influence across several domains or categories, the most measurable and consistent shift occurred in students' environmental awareness and sense of responsibility. The lack of significant change across many dimensions points to either the need for a longer stretch of time for the project or the possibility that certain constructs might require more targeted approaches for measurable shifts.

Students' perceptions and explanations of results

To deepen our understanding of the quantitative results, we followed the survey with a focus group of participating students ($n = 13$). During this focus group interview, we presented students with the significant shifts observed in the survey data and invited them to reflect on these changes. Specifically, we asked the students to evaluate whether these shifts aligned with their lived experiences and to identify and talk about aspects of the Highway 13 project that may have contributed to these shifts. The following sections thematically present students' interpretations of the survey results and their insights into the underlying factors that influenced these changes.

	Pre-Highway 13 Project			Post-Highway 13 Project			Change
	Like Me	Sort of Like Me	Not Like Me	Like Me	Sort of Like Me	Not Like Me	
Scientist	3	6	2	6	4	1	+4
Artist	9	2	0	8	3	0	-1
Advocate	1	5	5	5	4	2	+7
Inventor	1	5	5	2	8	1	+5
Good Community Member	4	7	0	9	2	0	+5
Leader	6	3	2	6	4	1	+1
Problem Solver	1	6	4	4	7	0	+7
Investigator	2	5	4	4	5	2	+4
Communicator	1	7	3	5	6	0	+7

FIGURE 4
Student affiliations before and after participating in the Highway 13 Project and net change over time.

TABLE 3 Wilcoxon signed-rank test results.

Category	Wilcoxon statistic	*p*-value
Community leadership	9	0.380
Environmental responsibility	1.5	0.019
Character development	24.5	0.447
Self esteem	17	0.154
Classroom community	17	0.887
Cooperative teamwork	8	0.257
Project engagement	10.5	0.553
Environmental interest and concern	10	0.139
Community impact	14	1.000
Project growth	8.5	0.671
Deepening relationships	17	0.154
Academic growth	3	0.223

Becoming advocates and change-makers through local action

As students engaged in the Highway 13 project, many began to see themselves as advocates for change in their local community. This shift in identity was rooted in students' sense of agency and their belief that their work could bring about meaningful environmental and civic change. Despite being in upper elementary grades, students did not view their age or status as a limitation. Rather, the experience of collecting data, analyzing patterns, and presenting findings cultivated a strong sense of purpose, voice, and self-belief.

This advocate identity was not abstract—it was connected to the tangible outcomes of their work. One student explained, "We made them realize what was actually happening and like how it needed to be changed," referring to how their findings helped to inform their local community on the dangers posed by speeding vehicles to wildlife. Another elaborated, "Even though [we] were just a little classroom that we can have a voice and speak." The opportunity to present at a school board meeting and to speak with representatives from the Wyoming Department of Transportation gave students firsthand experience in civic participation and built their belief in their ability to influence local decision-making.

When reflecting on what may have contributed to the development of this advocate identity, students pointed to the unique opportunities that this project offered. One student's response illustrates this aspect of the project's design particularly well: "Maybe before the Highway 13 project, [we] did not really do anything. Kind of…because [we] could not, but the Highway 13 project gave [us] a chance to change. That would make a difference." This response highlights the novel aspects of advocacy and community engagement that students were introduced to and invited to participate in with this project. Through this meaningful experience, students were able to begin exploring and embracing these new identity affiliations.

Importantly, this sense of advocacy was informed by evidence and scientific reasoning. While reflecting on the project progression, students explained that, "we figured out why it changed the speed limit," and "We understood the details." Further responses revealed that this depth of investigation and detailed reasoning drove students to be "convinced" of the necessity for designing an innovative community solution. These reflections point towards how knowledge production led to confident, action-oriented stances.

In these ways, the project enabled students to experience themselves not just as learners of science, but as active contributors to community problem-solving—an empowering shift that redefined what it meant to be a science learner in their context.

Cultivating responsibility to place and community

Through sustained engagement with a locally situated problem—wildlife-vehicle collisions along a well-known rural highway—students developed a heightened sense of responsibility to their community and environment. They did not see the project merely as a school assignment, but as an act of stewardship. Their comments revealed an emergent ecological identity, one that was tied to the specificities of place and underscored by a desire to protect it.

Several students voiced the belief that their work contributed to making the community safer: "Like in the community, we were safetying them more," and that they had a chance to "… fix the problem that has been there for a while." Their understanding of environmental responsibility was broad, encompassing the wellbeing of animals, people, and the land itself. While most reflections focused on maintaining a healthy environment and managing waste, some students offered more nuanced considerations. One student reflected that responsible behavior is evident when you "tak[e]charge of something without being asked or without people knowing what's happening." As another student explained, "Make sure that you can hunt and have food and that all of the animals do not get killed." These reflections point towards a complex understanding of responsible behavior shaped by their rural context, both in the deliberate and voluntary nature of action as well as moderation when providing for community. Ultimately, a final student summarized their perceptions of this responsible behavior as, "Helping to fix the place that you live in," pointing towards the disposition for active community contribution.

This sense of shared place was deepened through experiences like the field trip, where students moved from imagining to directly observing the spaces affected. "We got to learn more about like the area that we were observing instead of just like imagining what it looked like," one student noted, reflecting how place-based immersion supported relational, rather than detached, understandings of the environment.

The project thus fostered an understanding that local ecosystems, rural transportation practices, and human behavior are interconnected—and that students could play a role in maintaining the balance among them. In doing so, students began to adopt a relational identity grounded in care for place and collective responsibility.

Growing as communicators and knowledge builders

Communication emerged as both a skill and an identity anchor through the project. Students engaged in multiple modes of sharing—formal presentations, hallway map displays, peer-to-peer teaching, and data visualizations—which enabled them to see themselves as capable of producing and disseminating knowledge. Their sense of self as communicators and scientific thinkers developed not simply through the act of speaking, but through purposeful engagement with audiences beyond the classroom.

"Presenting at the board meeting," "sharing our animal reports," and "putting the map in the hallway so that everybody could see it during concerts" were frequently mentioned as meaningful opportunities to inform others. As one student reflected, "We communicated without actually talking to somebody," referring to how their hallway display sparked conversation and public engagement. Another described hearing parents "chattering amongst themselves" as they looked at the map and realized the significance of their work: "I think that they were definitely like agreeing with us about the environment." These responses underscore a developing awareness of variable media use that can lead to effective communication. Ultimately, students identified that the process of "finding what's happening, then sharing it" throughout each of these venues contributed to their sense of acting as a communicator.

Importantly, students also emphasized how their learning involved scientific practices, including data collection and interpretation. In discussing their experiments with braking distances, students explained, "We took bicycles… and we measured the distance… then we compared that data," and "We looked up how long it is and found out… the semi stopping brake is almost two football fields long." These experiences gave students tools to reason scientifically and then communicate those insights clearly—whether in presentations, conversations, or public materials.

Through these practices, students began to see communication not just as speaking or writing, but as a means of making their thinking visible, persuading others, and contributing to a shared understanding of local issues. As one student described, their intention became in "helping people understand… why this is happening and… how it's happening." This fostered a dual identity – as young scientists, and as capable, thoughtful contributors to community conversations.

Discussion

This study explored how a rural, place-based STEM project—the Highway 13 Project—influenced students' identity affiliations and self-perceptions. Through pre- and post-surveys and a focus group interview, we examined the ways students came to see themselves as scientists, advocates, problem-solvers, and communicators. Anchored in Carlone and Johnson's (2007) science identity framework and a PBE approach (Gruenewald, 2003; Vander Ark et al., 2020), this discussion interprets the findings in relation to the guiding research questions and theoretical commitments. We discuss how the Highway 13 Project shaped students' STEM identities, how these shifts aligned with competence, performance, and recognition, and how these findings contribute to the growing literature on PBE and place-based STEM in rural contexts.

Effect on self-perception and identity

The findings suggest that students' self-perceptions shifted as a result of participating in the Highway 13 Project, particularly in their identification as environmental stewards and advocates. The only statistically significant construct-level change across the pre-post surveys was in environmental responsibility ($p = 0.019$), underscoring students' growing sense of care for their local environment. This aligns with research showing that self-perceptions—students' beliefs about who they are and what they can do—are shaped by authentic and meaningful experiences (Schunk, 2020). In particular, Schunk (2020) notes that self-concepts are constructed through performance, reflection, and recognition within specific domains. As students gathered data, proposed solutions, and witnessed their ideas gain traction with adults in the community, their environmental self-concept became more robust. PBE literature also emphasizes that when students engage with real-world, community-embedded issues, they begin to see themselves as capable contributors to societal and ecological well-being (Buxton, 2010; Chawla and Derr, 2012; Sobel, 2004). The students' reflections—such as "we fixed a problem that has been there for a while"—demonstrate this emergent identity grounded in both environmental care and personal agency.

Carlone and Johnson's (2007) framework also helps explain these changes, especially with students' identity affiliations. The construct of competence—understanding and applying STEM knowledge—was evident as students engaged in authentic tasks like analyzing wildlife-vehicle collision data and mapping high-incident zones (Carlone and Johnson, 2007). Our findings also align with Varelas et al.'s (2013) work highlighting that even young children build disciplinary competence when immersed in science-rich environments that invite sensemaking and reflection. Similarly, Mercier and Carlone (2021) emphasize that competence can be demonstrated through diverse modes of engagement, especially when learners are given opportunities to develop and use knowledge in ways that feel relevant to their social worlds. The Highway 13 Project required students to draw from both scientific content and local understanding—creating a hybrid space where competence was contextualized and meaningful.

The project-based nature of the Highway 13 initiative enabled students to perform their developing identities in meaningful ways. Performance refers to the ways learners enact their identities through participation in science practices and social interactions (Carlone and Johnson, 2007). Research highlighting modes of engagement and identity development shows that when students engage in public-facing, multimodal forms of science—such as presenting, building, or designing—they enact identities that extend beyond academic labels and into community roles (Mercier and Carlone, 2021). In our study, students communicated scientific arguments using hallway maps, data displays, and oral presentations, offering multiple entry points for engaging in projects and performing themselves in various ways. These opportunities, as shown in our findings, align with Carlone and Mercier (2023) concept of identity play, as opposed to identity work—where youth experiment with new ways of being through science participation, especially in settings that are culturally and socially supportive. The Highway 13 Project allowed students to "try on" the role of environmental advocates, investigators, and leaders through performance-rich practices.

Recognition from peers, teachers, and community members was a critical factor in reinforcing students' evolving self-perceptions and identity affiliations. Being seen and treated as a "science person" is central to identity development (Carlone and Johnson, 2007; Gee, 2000). Varelas et al. (2013) argue that recognition is particularly important for younger children, who may be in the early stages of exploring how they relate to science. Public venues like the school board presentation or hallway displays functioned as moments of social validation, where students' ideas were taken seriously by adults in the community. In these moments, students were not only performing competence but being recognized as knowledgeable contributors—key to nurturing emerging identities.

The influence of rural and place-based STEM

The Highway 13 Project provided students with authentic opportunities to explore scientific practices embedded in their local rural context. As students investigated wildlife-vehicle collisions along a road they traveled regularly, their learning became grounded in a specific *place*—one with meaning, consequence, and relational ties to family, community, and land. This situated nature of the learning experience shaped how students came to see themselves—not just as learners of science, but as problem-solvers, communicators, and advocates with a responsibility to their community.

Our findings align with the literature centering PBE which emphasizes the power of learning rooted in local environments, cultural practices, and community issues (Gruenewald, 2003; Sobel, 2004). When students are positioned to engage with real-world phenomena in familiar contexts, they are more likely to make connections between academic content and personal relevance (Smith, 2017; German et al., 2023). This relevance fuels both engagement and identity development, especially when students recognize that their efforts can meaningfully affect their surroundings (Vander Ark et al., 2020).

In rural contexts, these place-based connections are particularly powerful. Research shows that rural youth often maintain strong affective and social ties to land, community, and local knowledge systems (Azano, 2011; Corbett, 2020). The students in our study demonstrated a deepening sense of environmental responsibility, civic agency, and community embeddedness as they collaborated with local residents, examined ecological data, and presented their findings to public audiences. These experiences reflect findings from Chawla and Derr (2012), who showed that participation in community-based environmental projects fosters self-efficacy and civic identity among youth.

Further, the project provided opportunities for students to be recognized and seen as a science person and invested community member (Carlone and Johnson, 2007). Presenting data to the school board, hearing family and community members discuss hallway maps, and interacting with community members positioned students as legitimate participants in science and community change. Davies (2021) argues that such public-facing communication of science, especially when scaffolded by caring adults and authentic tasks, allow students to play with and explore new identities—an essential process in middle-childhood and early adolescence learning and development.

The integrated nature of the Highway 13 Project—combining science, engineering, environmental studies, and civic action—also aligns with studies showing that interdisciplinary, community-connected STEM learning fosters both content learning, identity development, and student agency (Ballard et al., 2023; Cody and Biggers, 2019). When students engage in tasks that are both intellectually rigorous and socially meaningful, they begin to see themselves as capable of contributing to both scientific understanding and community well-being (Birmingham and Calabrese Barton, 2014).

In particular, our findings extend place-based STEM research by illustrating how rural settings offer distinct affordances for STEM education and identity and agency development. Students in this study received recognition from trusted adults, worked on a problem that was locally visible and emotionally salient, and experienced their school as a hub of community connection and change-making. These findings align with Corbett (2020) and Howley et al. (2011a,b), who argue that rural schools function not just as academic institutions, but as cultural and civic centers, making them uniquely positioned to host transformative place-based education.

Importantly, the students' developing roles as advocates and communicators emerged not only from the science content but from opportunities to interact with place and community. Their understanding of ecological systems was linked to a moral imperative to protect their local environment—what Buxton (2010) describes as critical, place-based science learning. As such, our study contributes to a growing body of research that demonstrates how PBE, when designed with STEM integration and a focus on authentic inquiry, can foster students' sense of self, sense of place, and sense of purpose (Hamilton and Marckini-Polk, 2023; German et al., 2023).

Implications for place-based STEM in rural contexts

This study contributes to a growing body of research that positions rural communities as fertile ground for innovation in STEM education (Corbett, 2020; Holmes et al., 2021). While much STEM education research centers urban settings or broad reform, our findings suggest that PBE in rural schools can uniquely foster STEM identity, agency, and community connectedness. The Highway 13 Project drew on local knowledge, fostered cross-generational dialogue, and engaged students in meaningful public communication—all of which are deeply aligned with rural educational values and the PBE framework (Gruenewald, 2003; Teton Science Schools, n.d.).

Limitations

This study has several potential limitations that may affect the interpretation and transferability of its findings. As a single-project case study, the results are inherently shaped by the specific context, student participants, and situated nature of the Highway 13 project. Like other project-based educational research studies, the findings may not be directly transferable to other settings. Additionally, rural contexts vary substantially across geographic and sociocultural landscapes (Hawley et al., 2016), meaning that similar educational experiences implemented in different rural communities could yield distinct outcomes. Constraints of small sample size and local context may therefore limit the generalizability of these findings.

Another important consideration is the evolving nature of students' definitions of key identity affiliation categories and student impact categories used in the study's survey. The survey categories were not predefined prior to survey administration or before the Highway 13 project began. As a result, students may have interpreted and responded to the survey items based on their own personal definitions and conceptualizations at the time of administration. Furthermore, engagement in the Highway 13 project itself may have influenced and reshaped students' understandings of these terms, introducing variability in how they perceived and applied these concepts between the pre- and post-surveys. The implications of these shifts were not fully captured until the post-project focus group interviews, where students had the opportunity to elaborate on their evolving perspectives. While these discussions provided valuable insight into students' conceptualizations, the lack of initial definitional clarity means that survey results reflect individualized interpretations rather than a shared, standardized understanding of the categories.

Furthermore, individual constructs measured within the survey instrument were defined using a limited range of specific items. While this approach may reduce the overall robustness of the constructs to define psychometric characteristics, item selection was intentionally grounded in a collaborative survey design process with classroom teachers. Although this may limit the generalizability of this paper's findings to other studies examining these constructs with more standardized measures, our prioritization to the participatory process sought to center the insights of those most closely involved in the experience. As Pain et al. (2015) suggest, individuals directly engaged in a phenomenon are often best positioned to define its meaningful outcomes.

Implications

In rural contexts, where access to STEM resources and opportunities can potentially be limited, place-based STEM education offers a powerful means to engage students in meaningful, community-connected learning. By anchoring STEM instruction in locally relevant issues—such as the Highway 13 Project's focus on wildlife-vehicle collisions—educators can foster deep engagement, scientific inquiry, and civic responsibility. Through these experiences, students do not simply learn STEM content; they see themselves as scientists, problem solvers, and advocates, actively shaping solutions to real-world problems in their own communities.

A place-based approach allows educators to integrate science, engineering, mathematics, and environmental literacy in ways that enhance student identity and agency. Designing interdisciplinary projects that incorporate authentic data collection, problem-solving, and collaboration with local experts can help students build scientific competencies while addressing local challenges. Encouraging students to communicate their findings through public presentations, visual mapping, and digital storytelling can further develop their ability to share scientific ideas and advocate for change. Schools that embrace this approach can create deeper connections between students and their communities, fostering a sense of purpose and belonging that supports long-term academic engagement.

Supporting place-based STEM education can help address disparities in STEM access and development in rural areas. Encouraging partnerships between schools, local agencies, and industry professionals can provide students with real-world learning experiences and exposure to STEM careers. Investing in teacher professional development focused on place-based and STEM-integrated instruction can ensure that educators have the skills and resources needed to implement meaningful, community-centered learning opportunities. By prioritizing this approach, rural schools can be positioned as hubs for innovation and local problem-solving, equipping students with the knowledge and confidence to contribute to both their communities and the broader STEM workforce.

Conclusion

The Highway 13 Project demonstrates the transformative potential of place-based STEM education in rural contexts. By engaging students with authentic local challenges, this approach fostered significant shifts in how students perceived themselves—as advocates, problem-solvers, community members, and environmentally responsible citizens. These identity transformations emerged not through abstract instruction but through meaningful participation in practices that connected classroom learning to community needs. Rural settings, sometimes overlooked in broader STEM education discussions, offer unique affordances for place-based learning that can address both academic goals and community sustainability. The geographic, cultural, and environmental contexts of rural communities provide rich opportunities for students to develop scientific competence while simultaneously strengthening their connection to place.

Place-based STEM education represents a powerful approach for rural schools facing resource limitations and geographic isolation. By leveraging local knowledge, environmental contexts, and community partnerships, educators can create learning experiences that are not only academically rigorous but also personally meaningful and civically productive. The Highway 13 Project illustrates how rural students, when given opportunities to investigate local phenomena and propose solutions to authentic problems, develop stronger STEM identities and a deeper sense of agency within their communities. This approach to education honors rural contexts while preparing students to address complex challenges through the integrated application of science, technology, engineering, and mathematics. As demonstrated by the fourth, fifth, and sixth-grade students at Willow Fork School, place-based STEM education can empower rural learners to see themselves as capable STEM practitioners and engaged citizens who can shape the future of their communities.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by University of Wyoming Institutional Review Board. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin. Written informed consent was obtained from the minor(s)' legal guardian/next of kin for the publication of any potentially identifiable images or data included in this article.

Author contributions

AM: Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. AS: Conceptualization, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. JT: Conceptualization, Writing – review & editing. KV: Conceptualization, Writing – review & editing.

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The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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