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Examining the Effects of Experiential Science Education in Middle School Classrooms

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ABSTRACT

This study investigated the impact of experiential science education on middle school teachers' practices and efficacy, as well as students' attitudes toward science. Teachers from four northeast Louisiana schools participated in a university-led professional development focused on the use of technology, data collection, and analysis through innovation in learning science, including school-based weather stations. Mixed methods were employed to examine classroom discourse and learning experiences within an interdisciplinary framework. Before intervention, analyses revealed no significant difference among schools, but showed varied (or heterogeneous) improvements afterward, demonstrating the site-specific/contextual effectiveness of the intervention. Post-hoc analyses revealed within-school variations across efficacy measures. Overall, findings post-intervention indicated reduced student anxiety toward science, enhanced perceptions of the societal value of science, and increased interest in pursuing science. The results highlight the potential of innovative, cross-disciplinary, *experiential approaches to strengthen both teaching practices and student engagement in science education.*

Keywords: citizen science, experiential education, mixed-method approach, place-based learning, science education

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INTRODUCTION

The critical role of students' prior knowledge and connections to daily life has been documented in shaping their interest and attitudes toward science (Barton, 1998). Innovative, lifelong learning methods, which emphasize intrinsic motivation and self-direction, have proven more effective for retention and engagement than traditional classroom curricula. A positive attitude towards science significantly boosts both short- and long-term engagement (Allchin, 2014). However, many prevailing states' policies which require passing either science or social studies rather than both, undermine students' motivation to learn science. This is especially concerning during adolescence, deemed a formative period for developing self-perception and career aspirations in science among middle school students.

LITERATURE REVIEW

Attitudes Towards Science

Studies reveal that fostering a positive attitude toward science involves showing students the relevance of science to their lives and the world around them. Adolescents' affinity for science often hinges on perceiving its importance and role in their everyday experiences (Owens, 2013). Research suggests that changing students' perceptions of science helps them see the role of science in their lives and uncovers their connection to science in daily life, which is a critical step influencing their attitude toward learning science (Belanger & Peters, 2008). Researchers advocate for participatory and practical learning approaches that enhance public understanding of scientific issues and research. These methods encourage students to connect classroom learning to real-world applications, nurturing both an appreciation for science and a desire for achievement. Expanding beyond traditional curricula to integrate experiential and relatable content can create more effective and engaging educational models (Anwar et al., 2022).

Understanding students' backgrounds and the influence of parental involvement is crucial for shaping their attitudes and self-beliefs toward science learning and career choices. Factors like cultural attitudes, parental support, and self-concept significantly impact students' motivation and achievements, particularly in minority communities (Pinder, 2013). Experiential education methods have been shown to positively influence students' attitudes toward science, which is vital as perceptions of scientists and self-belief can affect their interest in science-related careers (Suryawati & Osman, 2017; Weinberg et al., 2011). However, attitudes toward science often decline from elementary to high school, especially among minority students, emphasizing the need for interdisciplinary interventions that foster connections across disciplines and promote scientific reasoning and literacy. This study focuses on evaluating students' ability to connect content across disciplines within a teacher-designed interdisciplinary intervention. This approach aligns with the post-modern perspective of science education, emphasizing scientific thinking, reasoning, and connections (Bybee, 2014).

Middle school is a critical period for shaping long-term attitudes toward education, making it essential to balance formal and informal learning experiences to boost motivation and performance. Informal education, as defined by the NSF, emphasizes self-directed exploration and inquiry-based learning to foster critical thinking and excitement about science (NSF, 2013). These experiential approaches can counteract the limitations of standardized education by igniting curiosity and motivation in both students and teachers. Moreover, they are closely tied to teacher self-efficacy, making them an important focus for professional development programs aimed at enhancing science education outcomes (Owens, 2013).

Scientific Literacy

Scientific literacy encompasses a range of abilities, including understanding science’s impact on daily life, identifying research questions, and drawing evidence-based conclusions. It can also be participatory, as seen in citizen science initiatives, where individuals engage in activities like environmental monitoring, sustainable farming, or organic gardening (Roth & Barton, 2004). This concept links everyday experiences with learning, fostering relationships between the learner and varying content or contexts, especially in addressing challenges tied to industrialization and environmentally short-sighted development.

STEM education, driven by the global emphasis on improving scientific literacy, has become a priority in global competitions for the United States (Athanasia, 2022). This is critical, particularly for supporting disadvantaged youth, and is underscored by scientific literacy, which leads to improved science, technology, engineering, and mathematics education outcomes among students from diverse backgrounds (Donner & Wang, 2013). Researchers advocate for integrated approaches like project-based and inquiry-based approaches in informal settings, which surpass traditional methods (CSIS, 2022). Intermediary organizations, such as universities and non-profits, play a crucial role by offering strategic support, professional development, and innovative resources to promote effective science education (Clark et al., 2015). These ideas shaped the innovative intervention in this study, emphasizing systemic and collaborative approaches to advancing scientific literacy.

Role of Innovation in Learning Science

Students in traditional classrooms often struggle to engage in learning science and critical thinking, relying on abstract, theoretical textbooks that can be difficult for young learners. The direct instruction approach commonly used in K-12 science education is associated with low student attention and is influenced by personal relevance, attitudes, and beliefs about science (NSF, 2013; Xia et al., 2025). To address this, it is essential to create personal connections to science for learners, as this improves attention, understanding, and retention of concepts. Inquiry-based learning, emphasizing the evidence-explanation continuum and fostering dialectical discourse, has been found effective for engaging students and promoting meaningful conversations about scientific concepts (Hulleman & Harackiewicz, 2009). Certain aspects of a high-quality science curriculum have been identified, such as inquiry-based and hands-on learning, building parental involvement, bringing variety, and focusing on real, affordable, and sustained means of resources that are contextually relevant. Two very important factors that have been associated with high-quality learning experiences in science are – teachers' sense of self-efficacy and students' level of confidence (a positive attitudinal shift), and both of these were found to be positively affected by non-traditional systems of learning described above (Angle & Moseley, 2009; Donner &Yvonne, 2013). Teachers' sense of efficacy is seen as a combination of beliefs about teachers' own teaching capabilities, perception of efficacy in mitigating difficult classroom situations and/or reaching out to difficult students (Bandura, 1977; Tschannen-Moran, Woolfolk Hoy & Hoy, 1998).

The Local Context

Studies show that many learners, including K-12 students and adults, struggle with understanding the scientific process. While international assessments like PISA prioritize science, it is pertinent to discuss the way the overall science curriculum is structured in Louisiana, since the research study is situated there. Louisiana's state assessments (LEAP and iLEAP) omit science, which signifies a lower level of importance correlating with the state's low performance in science education. Even with recent improvements in Reading and Math (National Center for Education Statistics, 2024), Louisiana still ranks 44th nationally for overall K-12 performance (McCann, 2025). In Louisiana, science holds an optional status alongside social studies, requiring students to pass only one of the two subjects to advance, further diminishing its emphasis. This lack of prioritization undermines opportunities for improving science education. Given the conceptual overlap, improvements in math and reading scores could positively influence science performance, suggesting an integrated approach to addressing these deficiencies.

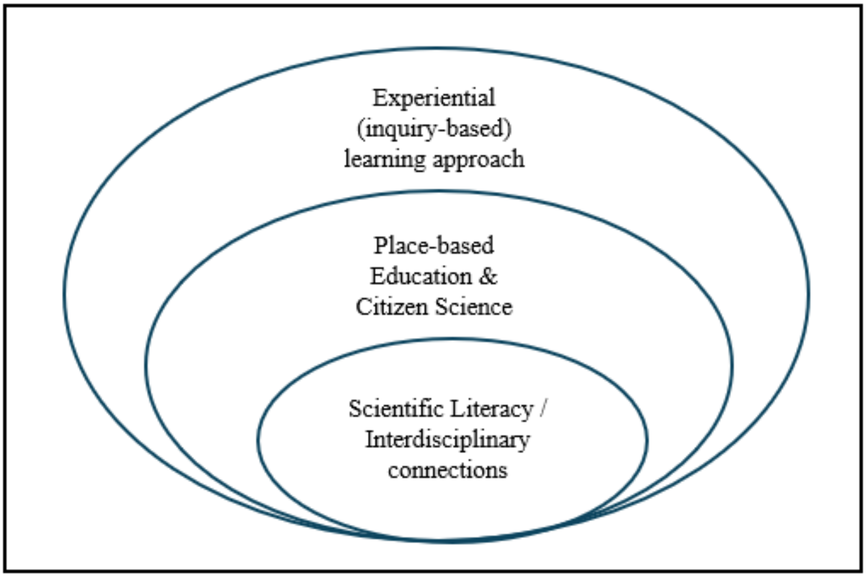
Therefore, this study aimed to assess shifts in students' attitudes towards science upon implementation of an innovative and cross-disciplinary, and school site-based science intervention. In addition, the role of the curricular model that evolved at each site, guided by the teachers' unique approaches, was also examined.

The following section begins with the conceptual framework, followed by the focus of research, methods, data analysis (both quantitative and qualitative), results, discussion, and conclusion.

Conceptual Framework

In this study, experiential learning is examined through the lenses of place-based education, citizen science, and scientific literacy (Stuever, 2009). The emphasis is on an interdisciplinary approach that integrates content areas, such as Sciences, Math, and English Language Arts, using Piaget's interactive curricular principles (Piaget, 1977). For instance, students at these sites were given the innovative challenge of developing a weather station (parts of which were supplied by the university team), negotiating its placement in the school backyard or vicinity. Class groups were then responsible for repetitive data collection practices, using which they were to achieve accuracy in the science classroom, analyze the data in Science or Math classrooms, and write about it and present the information in their ELA classrooms. Thus, students were tasked with using participatory science to build real-world skills and connections through this anchoring interdisciplinary learning. Linking these ideas housed within the multiple theoretical premises is the conceptual framework of the study, depicted in Figure 1.

Figure 1 *The conceptual framework connections*



Focus of Research

Conducted within a university-middle school partnership in northeast Louisiana, the study involved teachers and students from four middle schools. Using local resources, such as student-assembled weather stations, for scientific observation and cross-curricular integration, the approach aimed to enhance motivation, address challenges, and improve teaching and learning through field-based and interdisciplinary methods, demonstrating the potential of place-based, experiential science education to strengthen engagement and learning outcomes.

The goal of the research was to assess students' attitudes toward science and teachers' leadership using interdisciplinary interventions. A mixed-method approach was used to analyze both overall trends as well as detailed learning processes. The classroom intervention used in this study involved teacher-designed science units with interdisciplinary connections, tailored to each site through a university-school partnership. Central to the intervention were experiential learning principles like place-based education and citizen science, which emphasized scientific inquiry, data collection, and hands-on experiences for students. Additionally, the intervention fostered interactions and dialogue through classroom discussions, enhancing students' engagement and understanding of the scientific content. Using both quantitative and qualitative methods, this study explored *students' attitudes towards science, teachers' sense of self-efficacy, and the discourse of learning science.*

RESEARCH METHOD

Intervention

Designed with an emergent framework and open-ended instruments (e.g., observations), the study included a deeper look into the 'whys' and 'hows' of not just innovative activities, but how certain learning processes work in these settings and why and how innovative approaches can influence students' attitudes and perception of science using place-based education and citizen science, along with teachers' beliefs of self-efficacy, and their leadership through pedagogy. Students' attitudes toward science were studied through a survey assessing anxiety/self-efficacy, the societal value of science, self-concept, future interest in science, and perceptions of their science teacher (Weinbergh & Steele, 2000). Teachers' sense of self-efficacy was assessed through a teacher survey (Tschannen-Moran & Woolfolk Hoy, 2001). Teachers' sense of collective efficacy was evaluated through an item in the teacher interview, developed from the Teachers' sense of Collective Efficacy Scale (Goddard et al., 2004). The internal consistency index, standardized Cronbach's α, of reliability for the teacher survey questionnaire was 0.92 and that for the student survey questionnaire was 0.74. Both of these values were deemed adequate based on the generally accepted cutoff value of 0.70 (Nunnally & Bernstein, 1994). Together, the two constructs were considered as an indicator of teachers' sense of efficacy. Qualitative data were gathered through teacher interviews (pre- and post-intervention), classroom observations, and student focus group discussions to explore students' relationships with the content and their understanding of science.

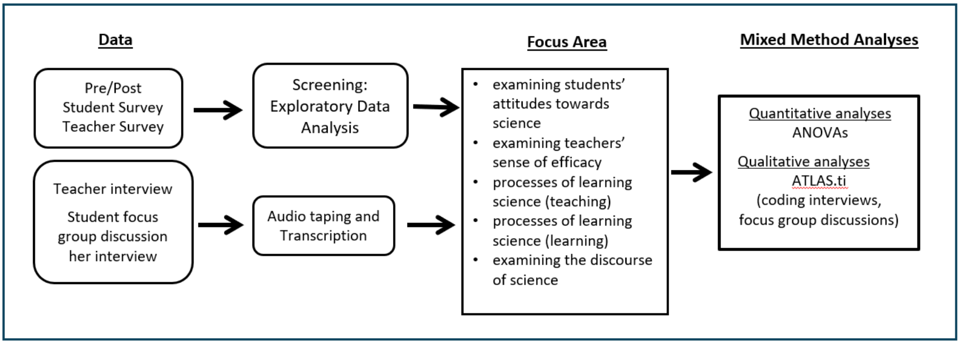
Before initial data collection, the researcher made contact with the individual teachers at a project workshop at the university. The teachers signed an agreement of understanding for this study. The project equipped teachers and students with technology, skills, and content knowledge to collect data and explore climatic trends, using school-based weather stations to connect concepts across Life, Physical, and Earth Sciences, as well as other subjects like ELA and Math. Students collected data in Life Science classrooms, discussed observed trends, plotted data, engaged in classroom discussions, reflected in journals, and read environmental science literature. These activities were also integrated into Physical/Earth Science and ELA classrooms. Overall, the study aimed to capture the lived experiences of students and teachers, with pre-and post-surveys providing numeric data on attitudes and self-efficacy.

Data Collection

A mixed-methods approach was used to combine qualitative and quantitative data, offering a comprehensive assessment of the intervention's impact on both student learning and teacher development. Data was collected from four middle schools, with six science teachers and four collaborating teachers from other content areas, such as ELA and Math, and 86 students participating in a collaborative project between a university and the four middle schools. The entire period of data collection lasted for about 10 weeks. Foci of data collection included student surveys to evaluate students' attitudes towards science. Also, teacher surveys were given to assess teachers' sense of efficacy. Classroom observations were made to study interactions among teacher-student-content during teaching and learning science, and emergent curricular patterns concerning the innovative, teacher-designed intervention at each site. The study comprised an explorative framework aimed at analyzing teaching and learning middle school science, as enacted through an experiential approach. A flowchart summarizing the various steps of data collection is presented in Figure 2.

Figure 2

Flowchart summarizing the data sources, screening techniques, important foci, and methods of data analyses. Data were collected from both student and teacher surveys at the four school sites (C, H, M, and R).



DATA ANALYSIS

Quantitative

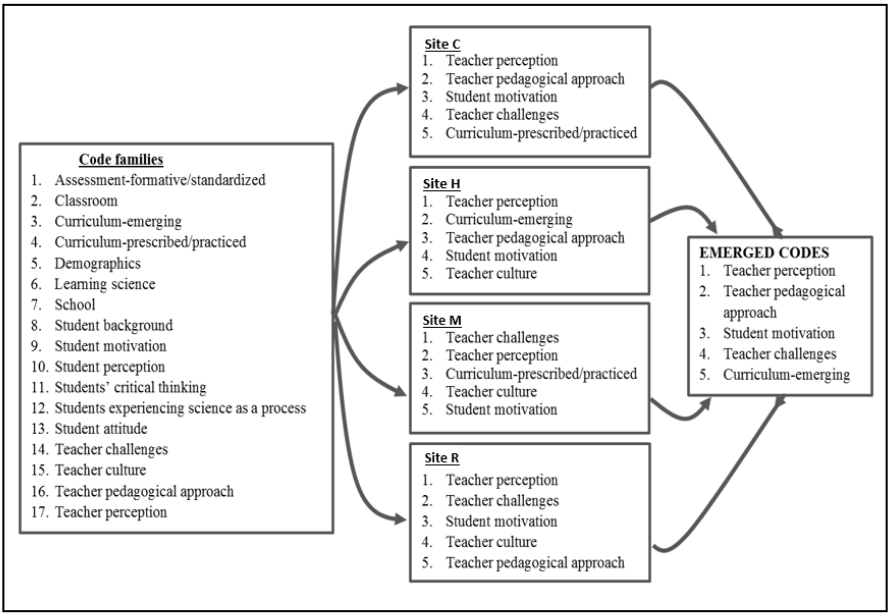
Descriptive analyses were carried out on data collected from student and teacher surveys at the four school sites. Additionally, a three-way factorial ANOVA was conducted to examine differences in survey scores by school, intervention (pre vs post), and subgroups. Subgroups constituted *a priori* categories within the surveys. The combined student attitude survey scores were treated as the dependent variable, and school and intervention (pre- and post-intervention) as the independent variables in the analyses. Teacher surveys were analyzed using a mixed factorial ANOVA, testing for three *a priori* subgroups-efficacy in student engagement, instructional strategies, and classroom management. All analyses were performed using statistical software R (R Core Team, 2024).

Qualitative

Qualitative data was collected from all four school sites through pre- and post-teacher interviews, on-site classroom observations, as well as observation of *ad hoc* student focus group discussions. Multiple forms of data collection served the purpose of triangulation to characterize, support, and compare findings (Fraenkel & Wallan, 2006). A flowchart summarizing both quantitative and qualitative data collection, as well as methods of analysis, is depicted in Figure 2. Thematic analysis was used in the study with the goal of identifying patterns in students' attitudes as well as an in-depth examination of how students constructed meaning out of their participatory learning experiences. Themes were generated inductively from the data, keeping these grounded in students' experiences. All the data used for qualitative analyses were transcribed and analyzed into categories of emergent codes using the software ATLAS.ti (Version 22) using the conceptual framework of the study (Dowling, 2008). Steps depicting the emergence of the top five themes in the study are shown in Figure 3.

Figure 3

Steps depicting qualitative findings leading to the emergence of the top five themes at the four school sites (C, H, M, and R).



RESULTS

Quantitative

The results of the descriptive data analysis for each of the subgroups constituting student surveys and grouped by schools are reported in Table 1. Data collected for students' attitudes towards science surveys were quantified for the four school sites and sub-categorized into the following five *a priori* subgroups (SG): SG 1- perception of the science teacher; SG 2- anxiety towards science; SG 3- value of science in society; SG 4- self-concept of science; and SG 5- desire to do science (Weinbergh & Steele, 2000). A summary of results by schools coded as sites H, C, M, and R appears in Table 1.

Table 1

Results from descriptive statistical analysis of student survey data. Mean scores before and after the intervention and standard errors of each subgroup are reported by site (C, H, M, and R). Note: In the column Trend, "+ve" and "-ve" indicate the positive and negative directionality of the change in scores, post-intervention.

Site	Sub-Group	Mean (±S.E)		Trend
		Pre	*Post*	*(+ or -)*

C	Perception of the science teacher	10.6 (0.6)	10.7 (0.7)	+ve
	Anxiety towards science	12.4 (0.7)	12.0 (0.9)	-ve
	Value of science in society	18.6 (0.9)	18.5 (1.0)	-ve
	Self-concept of science	13.8 (0.6)	14.5 (0.6)	+ve
	Desire to do science	21.1 (1.8)	21.3 (1.8)	+ve
M	Perception of the science teacher	9.4 (0.6)	9.9 (0.4)	+ve
	Anxiety towards science	14.4 (0.5)	14.1 (0.8)	-ve
	Value of science in society	15.7 (0.6)	17.6 (0.6)	+ve
	Self-concept of science	15.3 (0.5)	14.9 (0.6)	-ve
	Desire to do science	22.9 (0.9)	24.1 (0.9)	+ve
H	Perception of the science teacher	11.9 (0.5)	11.6 (0.5)	-ve
	Anxiety towards science	11.5 (0.6)	10.9 (0.7)	-ve
	Value of science in society	17.7 (1.3)	19.5 (0.8)	+ve
	Self-concept of science	13.9 (0.6)	12.9 (0.6)	-ve
	Desire to do science	25.7 (1.5)	26.6 (1.1)	+ve
R	Perception of the science teacher	9.6 (0.7)	9.8 (0.8)	+ve
	Anxiety towards science	11.9 (0.7)	11.4 (1.0)	-ve
	Value of science in society	15.8 (1.0)	17.7 (1.1)	+ve
	Self-concept of science	13.5 (0.5)	13.9 (0.9)	+ve
	Desire to do science	21.5 (1.5)	23.3 (1.7)	+ve

Overall, student anxiety toward science decreased post-intervention, and perceptions of science’s value and interest in pursuing science increased. At site H, all subgroup scores showed positive shifts, as indicated by a reduction in anxiety towards science, better perception of the science teacher, a higher self-concept of science, and an increase in students’ desire to engage in science. At sites C and M, anxiety toward science declined, and the perception of the science teacher improved. Site C also showed a higher self-concept of science and greater interest in science, and site M reported an increase in their desire to engage in science, along with greater students' desire to do science, post-intervention. Following the trends seen in other sites, there were higher scores for perceptions of the teacher, science’s value, self-concept, and desire to engage in science, along with reduced anxiety, at site R post-intervention.

Results of the ANOVA used to carry out a baseline comparison of subgroups' scores among the four sites before the intervention showed that there was no significant difference (F= 2.22; P= 0.091) in students' attitudes towards science at the beginning of the study. Next, the results of the ANOVA showed that there was no significant effect of the intervention (pre-post), or the three-way interaction among school, intervention, and subgroup. However, there was a significant two-way interaction between school and subgroup (F= 8.18; P< 0.001). This signified that the change in subgroup scores varied by schools. To parse these further, *post hoc* tests were used to examine these interaction effects. Table 2 shows the least square means for each site clustered by the sub-groups.

Table 2

Results of post hoc tests and least square means where the score for each school (C, H, M, and R) by sub-groups for the student survey. Significant differences (P < 0.05) are indicated by an "" asterisk.*

Subgroup		**F-value**	**P-value**	**Site**	**(LS means)**
Perception of the science teacher		7.28	0.0001*	C	(10.63)
	School	9.57	0.0001*	H	(11.73)
	Intervention	0.67	0.4151	M	(8.92)
				R	(9.84)
Anxiety towards science		2.81	0.026*	C	(12.17)
	School	3.73	0.012*	H	(11.13)
	Intervention	0.04	0.832	M	(12.77)
				R	(10.97)
Value of science in society		4.84	0.001*	C	(18.59)
	School	6.44	0.003*	H	(18.72)
	Intervention	0.01	0.949	M	(15.68)
				R	(17.09)
Self-concept of science		0.18	0.946	C	(14.07)
	School	0.23	0.875	H	(13.48)
	Intervention	0.05	0.828	M	(13.84)
				R	(13.62)
		7.35	0.001*	C	(21.21)
Desire to do science	School	9.81	0.001*	H	(25.88)
	Intervention	0.04	0.848	M	(19.73)
				R	(22.39)

For the perception of the science teacher, while there was no difference in pre-and post-intervention scores in this subgroup, however, there were significant differences within schools (F= 9.57; P= 0.001). *Post hoc* analysis showed that students' perception of the science teacher at site H scored the highest, followed by sites C, R, and M. Overall model testing difference in scores for students' anxiety towards science among schools was significant (F= 2.81; P= 0.026). Models that tested differences in science anxiety scores among schools were significant (F= 3.73; P= 0.01), but there was no effect of pre-and post-intervention on these scores. Students in sites H, C, and R had low anxiety associated with science, while site M had higher anxiety levels than the other sites. The overall model testing the effect of school and intervention (pre-post) on the value of science in society scores was significant (F= 4.84; P= 0.001). These scores were different among schools (F= 6.44; P= 0.001) while scores for intervention did not. In this subgroup, scores were the highest at site M, followed by sites R, C, and H. Overall model testing differences in students' self-concept of science scores by school or by intervention (pre-post) was not significant (F= 0.18; P= 0.946). The overall model testing the effect of school and intervention (pre-post) on the desire to do science was significant (F= 7.35; P= 0.001). Scores were significantly different among schools (F= 9.81; P= 0.001) but not for intervention (pre-post). The mean of scores for sites in the increasing order of magnitude were M, C, R, and H.

Next, in assessing teachers' sense of self-efficacy, through teacher surveys before and after the intervention across four school sites. Scores were categorized into three subgroups: (a) student engagement, (b) instructional strategies, and (c) classroom management for analyses. Results of the ANOVA testing differences in the above three categories by school and intervention, showed that while intervention did not significantly contribute to score differences, scores did vary by schools. Details of the analysis are presented in Table 3. For sub-group 1, efficacy in student engagement, teachers at site H scored significantly higher than teachers at site R. For sub-group 2 (efficacy in instructional strategies), site H scored the highest, followed by sites R and C, with site M scoring the lowest. For sub-group 3 (efficacy in classroom management), site H had the highest score, while site R had the lowest, and sites M and C had similar scores.

Table 3

Results of ANOVA evaluating differences in mean scores for the teacher survey among three subgroups, for the four school sites (C, H, M, and R).

Subgroups		**Site**	**Mean score** (± S.E)	**Main Effect Tests** (F and P-value)
Subgroup 1	*Efficacy in student engagement*	C	52.00 (2.00)	F = 4.31; P=0.032
		H	62.75 (2.56)	
		M	48.50 (6.06)	
		R	39.75 (2.59)	
Subgroup 2	*Efficacy in instructional strategies*	C	53.50 (4.50)	F = 3.54; P=0.053
		H	68.50 (2.22)	
		M	52.75 (4.66)	
		R	53.75 (3.20)	
Subgroup 3	*Efficacy in classroom management*	C	51.50 (2.50)	F = 6.43; P=0.010
		H	61.25 (1.25)	
		M	51.75 (2.32)	
		R	50.00 (2.12)	

Qualitative

Results for teachers' sense of collective efficacy as examined through teacher interviews, and the discourse of science as observed in classrooms and in ad hoc student discussions are reported in results. All qualitative results are arranged by sites.

Site C: At Site C, located in an economically depressed, rural community, the intervention was implemented solely by the science teacher, despite lacking a collaborator and facing administrative pressures to adhere to the prescribed curriculum. The teacher adopted an inquiry-based approach that significantly enriched the Life Science curriculum. Students engaged in activities such as collecting and analyzing local fauna with pitfall traps, correlating findings with weather data from the school's backyard weather station, and studying vegetation through photo plots. Classroom discussions integrated cultural perspectives on weather, fostering critical thinking and conceptual mapping. Student motivation was evident, though the intervention remained limited to Life Science, missing interdisciplinary integration.

Site H: Located in a rural farming community, at site H, the intervention benefited from a strong collaboration between the science and the ELA teachers. Together, they seamlessly integrated weather data analysis, seasonal trend mapping, and climate-based essay writing into their curricula. Students acted as news anchors, presenting findings and narrating climate-related events, blending scientific literacy with reflective learning through journaling and classroom discussions. Despite initial administrative resistance to installing a weather station, the teachers fostered a culture of student-led inquiry and active participation. This collaborative endeavor led to high student engagement within a curriculum aligned with state standards, making the intervention a success.

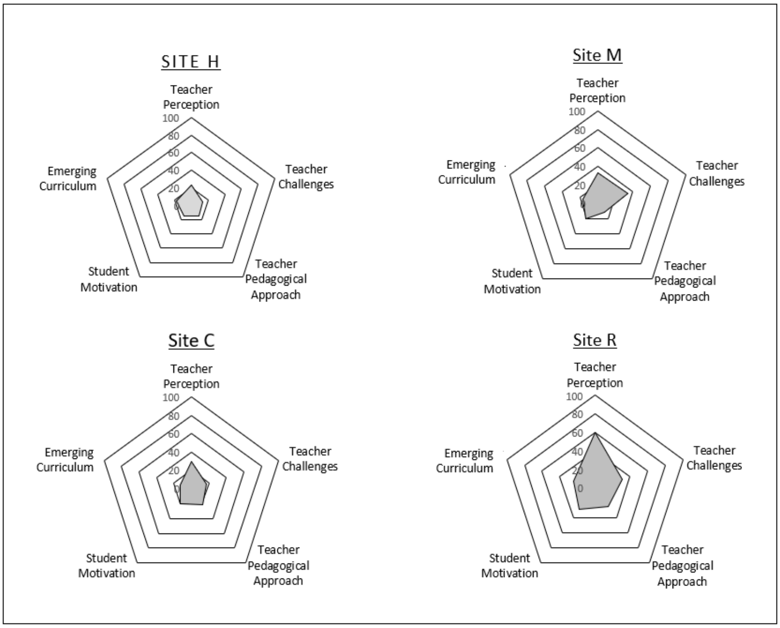
Site R: At site R, located in an urban area with a diverse student population, the intervention was collaboratively implemented by the Earth Science and Life Science teachers, with moderate contributions from ELA and Math teachers. Students collected weather data and insect samples using pitfall traps, analyzed their findings, and engaged in exploratory discussions about weather trends and impact on local fauna, including a Louisiana snapping turtle brought into the classroom. The weather station in the Earth Science teacher's classroom became a hub of curiosity, generating data that students shared with peers. While the administration supported these efforts, the level of teacher collaboration varied, with the Earth Science teacher contributing significantly more. This disparity resulted in a diverse yet effective learning experience that motivated students to see themselves as investigators.

Site M: At Site M, an urban, economically depressed community, the intervention was led primarily by the Physical Science teacher, with limited support from the Life Science and ELA teachers. The intervention featured intuitive, discussion-based activities such as analyzing weather data, seasonal tree photographs, and readings from the novel, The Lightning Thief, connecting mythical weather gods to real-world weather patterns, in the science teacher's classroom. This type of rich, dialogue-based interpretation of subject matter seemed to help students form an attachment to the intervention, which was evident in their fond conversations about their occasional adventure to the weather station. This resembled an intuitive and feminine approach that helped foster student enthusiasm and engagement (Fleener, 2004). Conversely, in the ELA teacher's classroom, the intervention was more rigid and teacher-directed, leading to limited student interest. Overall, administrative restrictions, financial constraints, and low collective efficacy among the teachers hindered broader implementation, making the intervention's success dependent on individual teacher approaches.

In an attempt to explore the processes of learning science among students, it was noted that with very similar content at the same grade levels, distinctly different curricular patterns emerged at the four school sites. Analyses revealed that no two schools interpreted the activities surrounding the weather station and complementary activities with the local vegetation/fauna in the same way. Even the character of the intervention uniquely evolved in each of the teachers' classroom(s) within the same school. The following patterns emerged from qualitative analyses (Figure 4).

Figure 4

A radar chart representing the relative magnitude of the five most prominent emergent themes across all four sites (H, C, R, and M).



Teacher Perception Led to Leadership and Innovation

Site H showcased exemplary collaborative leadership between science and ELA teachers, enabling a well-integrated and dynamic intervention. Whereas site C relied entirely on the science teacher's solo initiative, her innovation in Life Science was notable, though isolated due to a lack of support. On the other hand, site R featured uneven collaboration where the Physical Science teacher emerged as a strong leader, with others offering moderate contributions, leading to varied but meaningful outcomes.

While at site M there were stark contrasts in teacher leadership – where in the Life Science teacher's classroom intuitive, relational pedagogical approach fostered strong engagement, while others contributed minimally or ineffectively.

The emergent curriculum led to place-based and experiential learning

Sites H and C both embedded learning in rural ecosystems - students used pitfall traps, weather stations, and observations of the local environment to make science tangible. While site R adapted place-based learning to an urban context, using local fauna and weather patterns as focal points, including bringing in an alligator snapping turtle. Site M used limited outdoor access creatively through seasonal tree photography and localized storytelling to foster experiential connections.

Teacher's Pedagogical Approach Led to Interdisciplinary Integration

Site H was the most interdisciplinary, combining science, ELA, and media literacy with authentic student-led outputs (e.g., essays, news reports). Whereas, site C remained confined to science due to administrative barriers, missing cross-subject opportunities. Site R offered partial integration with modest contributions from Math and ELA, adding value without full collaboration. While at site M, integration happened primarily in Ms. MB's class through literature and science links; elsewhere, integration was minimal.

Student Motivation Led to Engagement and Empowerment

Sites H and R saw strong engagement through student-led inquiry and performance tasks (e.g., acting as news anchors or investigators). Whereas site C showed high motivation in science, but limited student empowerment beyond that. Site M revealed how pedagogical approach mattered - Ms. MB's intuitive teaching energized students, while rigid, top-down instruction elsewhere reduced engagement.

Teacher Challenges Categorized into Structural Constraints and Administrative Influence

Site H overcame administrative resistance to install infrastructure through collaboration. Whereas, site C was constrained by the administration's insistence on curriculum fidelity, limiting interdisciplinary expansion. Site R had administrative support but suffered from internal disparities in teacher involvement. While site M faced the greatest systemic barriers - financial limits, weak administrative support, and low collective efficacy - which fragmented implementation.

Overall, the success of the intervention correlated with strong teacher leadership. Sites H and M (only in the Life Science teacher's classroom) flourished due to empowered teachers, while Sites C and R were limited by disparities in teacher initiative. All four sites demonstrated that place-based learning is adaptable and powerful in both rural and urban contexts, though depth depended on teacher creativity and access to local data or environments. Deep interdisciplinary integration was rare but impactful (as at Site H), while partial or teacher-dependent efforts (Sites R and M) showed potential but lacked consistency. Engagement flourished in environments where students were trusted as active participants. Student voice and creativity were key drivers of success across sites. Administrative support (or lack thereof) heavily influenced scale and sustainability. Even with strong teacher effort, systemic constraints could blunt broader impact.

The five emergent themes varied across the four school sites, scored on a 0-100 scale. Post-intervention, *Teacher Leadership and Innovation* strongly influenced the outcomes at sites H, C, and R, driving the intervention's success. In contrast, at site M, *structural constraints and administrative influence* were the primary barriers, with *teacher leadership and innovation* and *student engagement and empowerment* also playing significant roles.

In the final analysis, teachers' perception of the intervention, their pedagogical approach, and the way they navigated challenges seemed to be pivotal in steering the intervention at specific sites. Also, student motivation, attitude, and involvement as someone thinking and acting like "real" scientists, were huge factors in making the intervention successful. With the above factors being positive, a rich, recursive, relational, and rigorous classroom curriculum emerged, much in congruence with the principles of an explorative post-modern approach.

DISCUSSION

Intersection Between Classroom Practices and Student Attitudes

The intervention acted as a window of opportunity for the transformation of the classroom environment in terms of the emergent curriculum across all sites. Quantitative analysis showed no significant difference in pre-intervention attitudes toward science among students, indicating that the intervention drove the observed changes in scores at individual sites, post-intervention. The inclusive design encouraged student engagement, with variations in involvement influencing site-specific results. For instance, at site M, an intuitive, collaborative approach emerged, fostering student-led data collection and analysis, even among peers less interested in science.

The intervention served as a platform for emergent curriculum patterns, offering real-world contexts that allowed students to construct personal meanings of scientific concepts. This contrasts with traditional science teaching, often focused on rote learning, abstraction and disconnected facts. Such approaches have historically marginalized minorities and women, whose learning styles often emphasize hands-on, organismal, or oral methods. By embracing inquiry and inclusiveness, the intervention helped redefine the approach to science education that resonates across diverse socioeconomic, cultural, and gender perspectives.

The Discourse of Science

Students actively build their identities through social interactions in the classroom and cultural experiences during inquiry-based learning, as in scientific investigations. The intervention provided opportunities for students to see themselves as scientifically literate, critical thinkers, or even citizen scientists by using and creating content across disciplines. For example, at site C, despite subtle administrative resistance, students enthusiastically engaged in rediscovering the woods near their school, collecting weather data from their backyard weather stations, and learning from hands-on experiences supported by appropriate teacher leadership. These formative experiences, enabled by a supportive environment, empower students to participate in future investigations (Firdausih & Aslan, 2025). As William Doll (1993) suggests, learning should liberate students to develop deep content understanding rather than focus on rigid targets.

Science Teachers' Experiences and Their Sense of Efficacy

Quantitative findings revealed that while teacher scores did not change pre- and post-intervention, they varied by site and theme. Site H had the highest teacher efficacy scores, along with student engagement and instructional strategy; site M scored the lowest. The concept of linear progress in schooling has long been challenged, with thinkers like Dewey (1956) advocating for active learning that values students' personal experiences (Boeve-De Pauw, 2022). Through site-specific interventions, teachers with higher self-efficacy were able to foster autobiographical elements, connecting students' experiences with the broader curriculum, aligning with a student-centered approach to an emergent curriculum (Cetin-Dindar, 2025; Tang, 2023).

The Trap of Hyper-Assessment and the Need for a Process-Oriented Approach

Assessment, a critical part of learning, should focus on both the process and product. Sites like H and C integrated formative as well as differentiated assessments, such as presentations, essays, and group discussions—enhancing reflection, communication, and collaboration, all important processes for learning documented in research literature as effective strategies teachers can implement to enhance students' learning experiences in science education (Slim et al., 2026). In contrast, narrowly interpreting the intervention as merely data collection wasted its potential. Hyper-assessment, or excessive focus on test scores, can alienate students, particularly minorities, leading to disengagement and dropouts (Dei et al., 1997). Standardized tests, while important measures used for validating success, cannot capture the breadth of students' abilities and may negatively impact both teacher efficacy and student motivation (Firestone & Pennell, 1993). A balanced, inclusive, and empathetic approach to assessment is essential for academic engagement and social justice (Anogwih, 2023).

In a survey conducted by the Louisiana Association of Educators, 78% of member-educators expressed the belief that assessments aimed at measuring student success were consuming valuable classroom hours. This finding aligns with the National Education Association's research, where over 50% of teachers across the nation reported spending excessive time on test preparation. Some teachers even contemplated changing careers due to the persistent pressure for standardized testing (Louisiana Association of Educators, 2015). In addition, teachers' limited usage of evaluation data from standardized tests proves that it is of little to no assistance post priori (Ford, 2018).

The Contextual Paradigm Shift That Also Shapes the (Classroom) Curriculum

The historical trajectory in education highlights a gradual shift from rigid, factory-like schooling of the 19th century to a more dynamic approach in the 20th century. Scholars like William Pinar (1975) introduced the concept of reconceptualized curriculum, emphasizing self-reflection and conscious experience, enabling students to see themselves in the learning process. This flows with the concept of experiential learning that bridges the gap between theoretical abstraction and learning in practice (Malik & Behera, 2024).

Classroom realities often differ from prescribed curricula, which are heavily influenced by political and market-driven pressures equating learning to information packets exchanged for grades. This outdated, industrial-age model does not align with the interconnected, post-industrial world, where learning thrives as an integrated, contextual process. Also, top-down and unsupported shifts in K-12 teaching expectations create undue pressure on teachers, limiting their ability to facilitate situated, contextual learning (Aikenhead, 2023).

Citizen science offers an alternative by immersing students in local contexts where they become experts in their collected data. This approach challenges generalized narratives in education and fosters active participation through meaningful fieldwork. Students transition from passive observers to engaged participants, building relationships with the content and deepening comprehension. While not every topic requires elaborate exploration, a few anchor experiences can contextualize broader studies even within practical constraints (Zhang, et al., 2023). As the teacher at Site C observed, the intervention revealed the rich process underlying scripted science, mirroring real scientific inquiry. By experiencing this firsthand, students connected with the content and developed a deeper understanding of the scientific process. While in the process, students had an opportunity to grow from an attitude of disconnect or worse, anxiety, to engagement through fostering positive learning experiences.

REFLECTIONS & IMPLICATIONS

Opposition to change and bringing innovation in schools remains a significant challenge, as observed in this study. Uncertainty, lack of information, and political tensions have created a restrictive environment for teaching and learning. Some teachers, such as the Life Science teachers at sites R and M, limited the intervention to a small group of students, failing to engage all learners or provide them with access to the rationale behind the curriculum. This lack of inclusiveness hindered student ownership of the intervention, contrary to the inclusive approach encouraged by the Common Core standards.

The study highlighted that student attitudes and teacher efficacy are heavily influenced by the conditions and curricular options they encounter, including pressures from hyper-assessment and accountability measures. In today’s world, science plays a dual role: a tool for progress and innovation, but it could also be pursued as an overemphasized pursuit at its extreme. This modern paradigm often prioritizes the utility of science over a balanced educational approach.

Future research should focus on developing and testing distinct curricular models tailored for rural and urban contexts (Cao, 2025). Partnerships between universities and schools could enhance teacher efficacy and provide richer science experiences for both teachers and students, as evident in this study. Additionally, fostering collective teacher efficacy within individual schools is crucial for creating sustainable, interdisciplinary projects. Research should also explore teacher-student interactions that facilitate experiential learning, as well as visual analyses of how students perceive science and its connection to their attitudes (Vydra, 2025). Such studies would offer valuable insights into the discourse of science while supporting the reconceptualization of experiential education in today’s context.

In conclusion, fostering innovation and inclusiveness in science education requires addressing systemic barriers, supporting teacher efficacy, and creating context-sensitive curricular models. By prioritizing experiential learning, interdisciplinary collaboration, and tailored approaches for diverse educational settings, science education could be reshaped to be more engaging and equitable. A reconceptualized approach not only prepares students to navigate the complexities of modern science but also encourages a deeper connection with learning that is both meaningful and transformative.

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